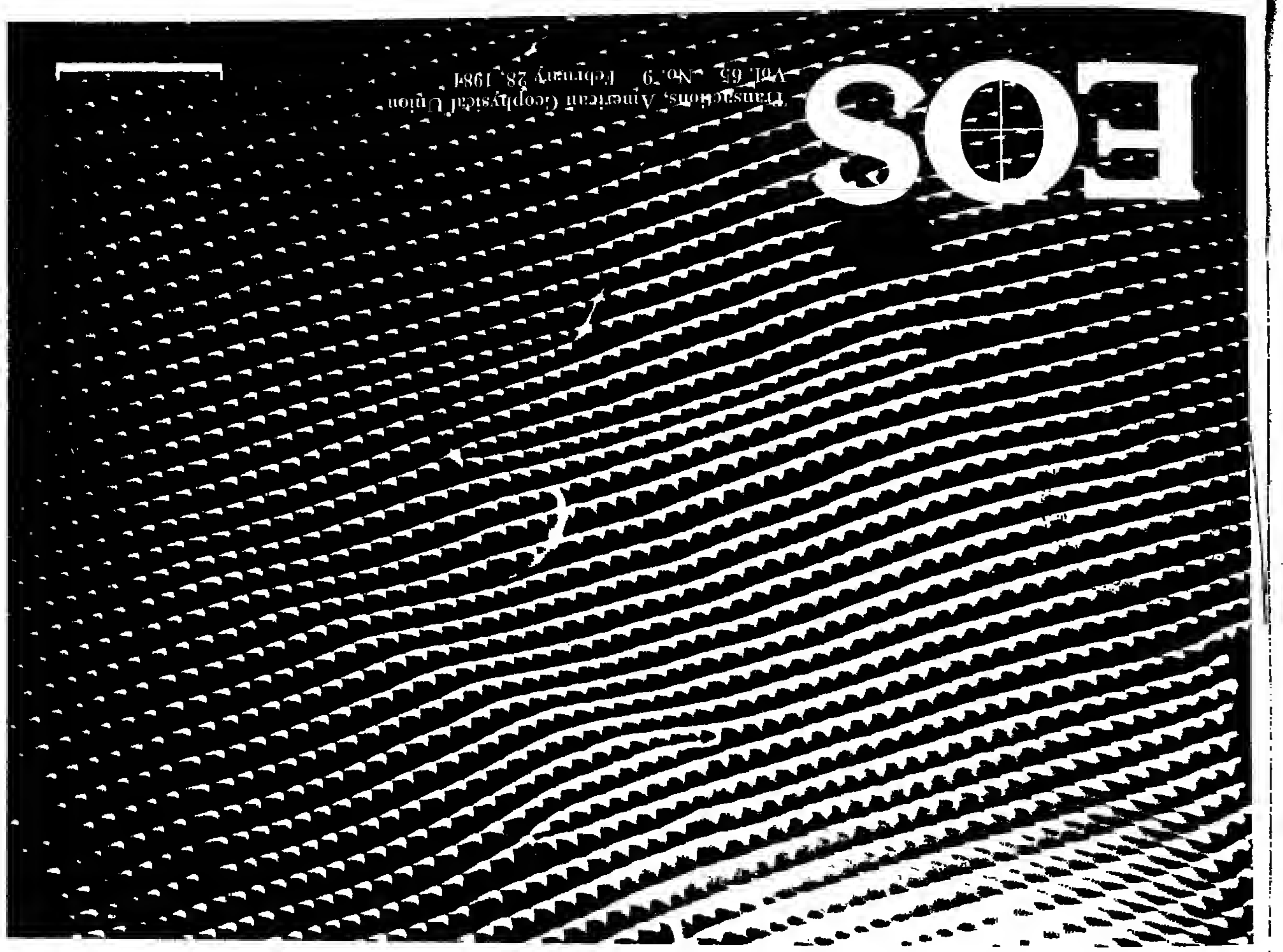

Eos, Transactions, American Geophysical Union Vol. 65, No. 9, Pages 73–80 February 28, 1984

Physical Properties of Rocks

5110 Elasticity, fracture, and flow
SUBCRITICAL CRACK GROWTH IN GEOLOGICAL MATERIALS
B. K. Atkinson (Geology Department, Imperial College, London SW7 2BP, Britain)

A review is presented of the experimental data on subcritical crack growth in geological materials. The main parameters describing subcritical crack growth are the critical stress intensity factor (K_c), the subcritical crack growth limit (K_0), and the stress intensity factor/crack velocity (K–v) relationship between K_0 and K_c. The K–v data are presented in terms of an equation in which the crack velocity depends on stress intensity factor raised to a power, n, because this is common practice in experimental studies. These data are presented as tables and in synoptic diagrams. For silicates, the value of n increases as the environment becomes depleted in hydroxyl species and with increase in the microstructural complexity of the solid. Values of n as low as 9.5 have been found for tensile cracking of quartz in basic aqueous environments, and as high as 170 for tensile cracking of basalt in moist air. Insufficient experimental data are available to predict subcritical crack growth behaviour at depth in the Earth's crust without major extrapolation of the data base. Schematic outlines are presented, therefore, of the probable influence on subcritical crack growth of more key parameters in the crustal environment. These include: stress intensity factor, temperature, pressure, activity of corrosive environmental agent, microstructure and residual strains. In addition, a discussion is presented of the likely magnitude of the subcritical crack growth limit. For stress corrosion tensile crack growth of quartz a limit of approximately 0.2 of the critical stress intensity factor is inferred from theoretical calculations. Further problems discussed with regard to the extrapolation of experimental data to crustal conditions include the choice of a suitable equation to describe crack growth and the magnitude of n in these equations. A brief discussion of the double torsion testing method is presented in order to aid the interpretation of experimental results because it is almost the sole method used to study subcritical cracking in rocks. (Subcritical cracking, fracture mechanics, extrapolation to nature, experimental methods).
J. Geophys. Res., B, Paper 4B0210

5110 Elasticity, fracture, and flow
FLOW STRENGTHS OF QUARTZ AGGREGATES: GRAIN SIZE AND PRESSURE EFFECTS DUE TO HYDROLYTIC WEAKENING
A. K. Kronenberg and J. Tullis (Department of Geological Sciences, Brown University, Providence, Rhode Island, 02912)

Novaculites and quartzite ranging in grain size from 1.7 to 211 μm have been experimentally deformed at confining pressures of 350 to 1620 MPa under conditions of constant displacement rate and constant deviatoric stress, in order to determine both the effects of grain size and pressure on the rheology of quartzite. The amount of water available to the samples was varied so that [illegible]

of the mechanical data, in combination with microstructural observations, are inconsistent with existing models of intrinsic grain boundary effects. Instead the strength-grain size relations are interpreted as resulting from variations in structurally incorporated water, which in turn are controlled by diffusion of water to and from the grain boundaries. Finally, constant stress experiments show that the activation energy Q and stress exponent n for creep do not depend on grain size, so that the different strengths observed must be incorporated in the pre-exponential terms. However, both Q and n show a continuous decrease with increasing amounts of available water, from Q = 360 kJ/mole and n = 4 for vacuum-heated samples, to Q = 130 kJ/mole and n = 2.8 for water-added samples.
J. Geophys. Res., B, Paper 3B1350

Seismology

6905 Body Waves
HIGH FREQUENCY ACOUSTIC BACKSCATTERING AND SEISMIC ATTENUATION
Anton M. Dainty (School of Geophysical Sciences, Georgia Institute of Technology, Atlanta, Georgia 30332)

The expression for the backscattered intensity of acoustic waves singly scattered from a region containing fluctuations of the acoustic velocity has been derived for high frequencies by expanding the autocorrelation of the slowness fluctuations in a Taylor series about zero lag. The resulting expression indicates that the backscattered intensity is independent of frequency and directly proportional to the first derivative of the autocorrelation at zero lag; the next higher term is proportional to the reciprocal of the square of the frequency and directly proportional to the third derivative of the autocorrelation at zero lag. Contributions from terms of the Taylor series involving even numbered derivatives of the autocorrelation are zero. Since for the autocorrelation of a smooth function only the even numbered derivatives are non-zero at zero lag, this result demonstrates that backscattering at high frequencies can occur from discontinuities of velocity or its derivatives as opposed to fluctuations in which the velocities are smooth. If the backscattered intensity is independent of frequency, the contribution of backscattering to the attenuation parameter Q is proportional to frequency. Such behavior may have been observed for seismic waves of frequencies greater than 1 Hz, suggesting that scattering from discontinuities is an important part of the attenuation of such waves. (Acoustic scattering, seismic attenuation).
J. Geophys. Res., B, Paper 4B0124

Tectonophysics

8150 Plate Tectonics
RECENT FAULTING AND MICROEARTHQUAKES AT THE INTERSECTION OF THE VEMA FRACTURE ZONE AND THE MID-ATLANTIC RIDGE
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New airgun reflection profiles, 3.5 kHz reflection profiles and microearthquake data recorded by an array of ocean bottom seismographs form the basis for this study of the transition from a spreading center to a major transform fault. Disturbances of the thick, normally flat-lying, turbidite deposits provide indications of recent vertical motions. At the western intersection of the fracture zone with the median valley there is a depression in the sediments that represents the southerly extension of the median valley into the fracture zone valley. The depression is terminated abruptly on the south by the active transform fault, which acts as a locus for vertical as well as horizontal displacement. Flat-lying, undisturbed sediments terminate abruptly at the fault. The western boundary of the depression is much broader and is characterized by a series of slump-like steps. To the west, there is little or no evidence for uplift or tilting of sediments which might indicate vertical recovery of the crust [illegible] the depression. This suggests that [illegible] recovery out of the depression is episodic in nature and has been inactive the last million years along the western boundary. To the east, there is clear evidence of uplift and tilting of sedimentary layers. A basement ridge emerging from the sediments is currently being uplifted and rotated in a manner analogous to processes responsible for the creation and cancellation of median valley relief. The transition between the spreading center and the transform fault appears to take place within 1 to 2 km. The width of the transform fault just east of the depression is less than a kilometer. Microearthquakes were located and displayed by new methods that directly account for nonlinearities associated with small arrays. Microearthquakes located by 3 or more OBS's show that the greatest seismic activity occurs along the eastern walls of the median valley, at the basement ridge, in the eastern portion of the depression and in the frontal mountains. Very little activity is associated with the western edge of the transform depression and the trace of the transform fault.
J. Geophys. Res., B, Paper 4B0195

8170 Structure of the Lithosphere
GEOID HEIGHTS OVER THE LOUISVILLE RIDGE (SOUTH PACIFIC)
A. Cazenave and K. Dominh (Groupe de Recherches de Géodésie Spatiale, CNES, 31055 Toulouse Cédex - France)

Geoid heights over the Louisville Ridge seamount chain, deduced from the Seasat satellite altimeter data, have been analyzed and interpreted. Two uncharted seamounts belonging to the chain have been detected. The elastic thickness of the oceanic lithosphere has been determined along the chain. This was done rigorously using the two-dimensional geoid and bathymetry maps and was also computed approximately using spectral methods on geoid and bathymetry profiles. A slightly increasing elastic thickness from the southeast to the northwest, in the range 15.5 – 23.5 km has been estimated. Together with dating measurements available for two seamounts of the chain, this result strongly favours the elastic model – compared to the visco-elastic model – for the flexure of the oceanic lithosphere in response to loading.
J. Geophys. Res., B, Paper 4B0149

8199 General
CONTINENTAL MARGINS, AND THE EXTENT AND NUMBER OF THE CONTINENTS
J. Graham Cogley (Geography Department, Trent University, Peterborough, Ontario, CANADA K9J 7B8)

A new map of the extent of continental crust shows that the continents are more extensive and less dispersed than they are conventionally thought to be. Their total area is 210.4 x 10^6 km^2, or 41% of the Earth's surface, and there are 14 of them. In order of decreasing size they are Eurasia, North America, Africa, South America, Antarctica, Australia, India, Arabia, New Zealand, Central America, Rockall, Seychelles, Agulhas and Jan Mayen. Continent-ocean contacts are mapped on the basis of a literature survey, and continent-continent contacts are drawn along plate boundaries. The average thickness of continental crust is 36 km; small continents seem to be thinner than large ones, and height and thickness are strongly interdependent. Mean heights are significantly lower than in previous estimates because submerged parts of the continents (30.6% of their total area) are correctly accounted for; the new estimate of mean height is ~120 m. The relationship between mean height and area for individual continents, however, is still observed. Modal heights are not correlated with area, and are ~300 m for most of the large continents. Certain continents have anomalous mean or modal heights, suggesting that the mean height-area relationship arises from greater relative lengths of orogenic belts around and internal tectonism within larger continents; anomalous modal heights suggest anomalous epeirogenic activity. These results may have implications for the hypsometry of ancient continents; in particular, Pangea need not have had a modal height much different from that observed today.
Rev. Geophys. Space Phys. [illegible]

The Potential of Satellite-Based Radar Altimeters

C. N. K. Mooers,[1] D. E. Barrick,[2] R. E. Cheney,[3] D. B. Lame,[4] and J. G. Marsh[5]

Introduction

Seasat is the only dedicated, multisensor oceanographic satellite to have ever flown. Although the mission lasted for only 3 months in 1978, it returned an enormous harvest of unique and valuable data that are still in the early stages of analysis. Its sensor complement included a scatterometer for surface winds, a passive microwave radiometer for sea surface thermal measurements, a synthetic aperture radar system for ocean surface imaging, and the radar altimeter. The altimeter provides information on significant wave height, surface wind speed, and above all, the topography of the sea surface. This topography is of prime interest to ocean circulation studies because its horizontal gradient, after removal of the geoidal signal, is proportional to the surface geostrophic current, the principal circulation component.

Satellite altimetry was introduced as a brief experiment on Skylab in 1973, followed by the 3.5 year GEOS-3 limited coverage mission which was launched in 1975. Seasat provided a superior altimeter system with decimeter accuracy and data recording capability which provided global coverage.

Looking to the future, the Navy plans to launch the altimetric satellite GEOSAT in 1984 for geodetic applications. This mission has oceanography as a secondary objective. The Navy is also planning NROSS (Navy Remote Ocean Satellite System), a Seasat type of mission, for 1988. The National Aeronautics and Space Administration (NASA) is preparing to launch TOPEX (Topography of the Ocean Experiment) in the same time frame with an orbit, a tracking system, and a highly accurate altimeter optimized for the study of ocean circulation. The European Space Agency is including an altimeter on the ERS-1 (European Remote Sensing) satellite in 1988, and the French Space Agency is considering the addition of an altimeter (POSEIDON) to their SPOT satellite in the late 1980's.

The Seasat Altimeter Data Seminar, held November 2–4, 1982, at the Jet Propulsion Laboratory (JPL), in Pasadena, Calif., brought together sensor and system engineers, geodesists, physical oceanographers, geophysicists, data managers, and others to consider the practical and scientific potential of satellite-based radar altimeters, especially those comparable to or better than Seasat. With much novel data in hand, and with the prospect of a major increase in activity in a few years, this seminar was held at a propitious moment in the history of ocean science.

The goals of the seminar were to review the information content of satellite altimetry for ocean science, to produce synergistic interactions in a unique aggregation of engineers and scientists, and to characterize the capabilities of satellite altimeters of the past and future. Ancillary objectives included (1) improving and broadening the use of satellite altimetry in ocean science for the betterment of the TOPEX program and (2) defining the needs of the scientific community for improved data base management for satellite altimetry through PODS (Pilot Ocean Data System). The purpose of this article is to provide a summary of these topics to the broadest possible scientific community.

Measurement Systems

Use of a satellite altimeter to acquire accurate sea-surface information for oceanographic and geodetic purposes requires (1) an understanding of the interaction of the short radar pulse with the sea surface, (2) an effective altimeter system, and (3) algorithms for extracting geophysical variables. These three aspects are interrelated and produce the ultimate limits on measurement system accuracy. Understanding these accuracy limits—or error budgets—is essential for sensible use of the data and for the improvement of the next generation of altimeters.

There are several sources of error in the altimeter measurement system; some of these errors arise from the interaction of a radar pulse with the sea surface. The tracker bias and additional tracker error produced by waveheight skewness tend to drive the tracking gate location too low; this bias is easily identified and therefore removed. Altimeter performance anomalies, i.e., periods when the height-tracker measurement appears to go badly awry, can also be detected and removed. Antenna-pointing error and heavy rain cause a decrease in the plateau amplitude of the mean return and, hence, in the backscatter coefficient. Rain distorts the echo during storms, which may produce gross overestimates of windspeed if not corrected.

Discrepancies also exist between wind speeds at nadir estimated from the altimeter (on Seasat) and the scatterometer. These discrepancies have not yet been resolved. A deconvolutional algorithm for extracting the waveheight-waveslope probability density directly from the echo, with no use of a priori models, has been demonstrated; uncertainties in parameter estimates obtained therefrom are routinely provided with a high degree of computational efficiency. Progress is being made in understanding and reducing all sources of height error, to the point that a satellite such as TOPEX could have a one-sigma total height error as low as 14 cm for the baseline mission and as low as 6.7 cm with a more accurate tracking system.

Present theories do not account for electromagnetic (EM) bias in a satisfactory manner. Based on EM bias measurements from aircraft at 10 GHz and 36 GHz, the bias at the higher frequency is a factor of 3 smaller than that at the lower frequency. Scatter in measured EM bias values is high, and attempts to correlate it with various factors (e.g., skewness, kurtosis, etc.) produced disagreement between the results at the two frequencies. Further puzzling results have been obtained with laser measurements which showed that, in swell-dominated conditions, EM bias appeared to be positive and height skewness negative (i.e., waves are sharper at the troughs than crests). With EM bias simulated in a wavetank, when wind blows across the longer waves, shorter waves are more prominent on the crests than on the troughs, resulting in more intense scatter from the trough regions (consistent with EM bias). A method based on the Rayleigh criterion for deciding where to cut off the spectrum in estimating EM bias is a possible solution.

Finally, among advanced concepts, the use of a multibeam altimeter appears intriguing. By merely adding another 1.2-m antenna and separating the two antennas by 11 m, a cross-track swath centered on nadir is produced. By simultaneous use of range-gating with the interferometric gating lobes on the surface, heights at -50 km, nadir, and +50 km could be measured simultaneously, permitting a more synoptic mapping of mesoscale ocean variability.

Orbit Computation and Mean Sea Surfaces

There are four components to the determination of the satellite orbital path: (1) the differential equations which describe the motion of the satellites, (2) the solution of these differential equations, (3) the measurement of the satellite translational motion, and (4) the solution technique which enables estimation of the orbit, geodetic, geophysical, and oceanographic parameters from the first three components.

Tracking data are required to determine the orbit. Weighted least squares are used to solve for the position and velocity which best fit the tracking data. The differential equations of translational motion require accurate models of all forces acting on the satellite, including those of gravitational and nongravitational origin. Ground-based measurements also require modeling of the orientation of the earth in space with respect to the moon, sun, and planets and the orientation of the earth with respect to the angular velocity vector. The location of the tracking instrument on the earth is also required.

Precision orbit determination has been primarily limited by incomplete global tracking, errors in the model constants, or in the models of the physical forces acting on the satellite, most notably the earth's gravity model. The radial accuracy of the orbits contained in the Seasat geophysical data record (GDR) was approximately 1.5 m. A significant improvement in the earth's gravity model has since been achieved by incorporation of the Seasat altimeter data in the model adjustment process. The altimeter data are especially useful since they are accurate and very dense coverage over the oceans is available. The improved model, called PGS-S4, has yielded radial orbit accuracy of better than 1 m when used with laser and Unified S-Band data in orbital lengths of several days.

Recent computations using the PGS-S4 model with Seasat Tranet Doppler tracking data over arc lengths ranging from 2 revolutions to a few days have provided radial orbit accuracy of better than 50 cm. High-precision laser tracking data from LAGEOS and Starlette are also being included in these analyses to provide information on the low-degree gravity model coefficients, tracking station coordinates, polar motion, and earth rotation parameters. An experimental tracking system call SERIES-X is under development for TOPEX. This concept uses differential ranging to the Global Positioning System satellites and may improve orbit accuracy to the sub-decimeter level.

Another new technique for improving orbit accuracy employs a nondynamical algorithm for correcting the radial ephemeris of Seasat. The model used for altitude ephemeris error is a Fourier series whose independent variable is time. The solution involves both crossover data and along-track data. Only weak (approximately 5 m) a priori knowledge of the geoid and no information on dynamic ocean heights is required. With a 3-day arc of Seasat data the altitude error was reduced to 6 cm.

Precision orbital computations and the altimeter data have been combined to produce global maps of the mean sea surface. The GEOS-3 and Seasat altimeter data have been used to compute a global representation of the mean sea surface on a 1° x 1° grid. The Seasat ephemerides were based upon 6-day arcs of laser and unified S-band tracking data computed with the PGS-S4 gravity model. The GEOS-3 altimeter data were adjusted into a common reference system using a combination of laser reference orbits and crossing-arc adjustment techniques. In addition to the global solution, regional solutions have been computed in the North Atlantic, North Pacific, Bering Sea, and the Gulf of Mexico (Figure 1). These regional solutions have been gridded with horizontal resolutions as fine as 15 km; their precision is of the order of 10 cm.

Wind, Waves, and Tides

From the amplitude of the altimeter's mean return power waveform, wind speed can be estimated. Significant wave height can be estimated from the stretching of the altimeter return. Furthermore, minimum swell height can be determined by assuming that the measured wave height consists of energy due to

Article *(cont. on p. 86)*

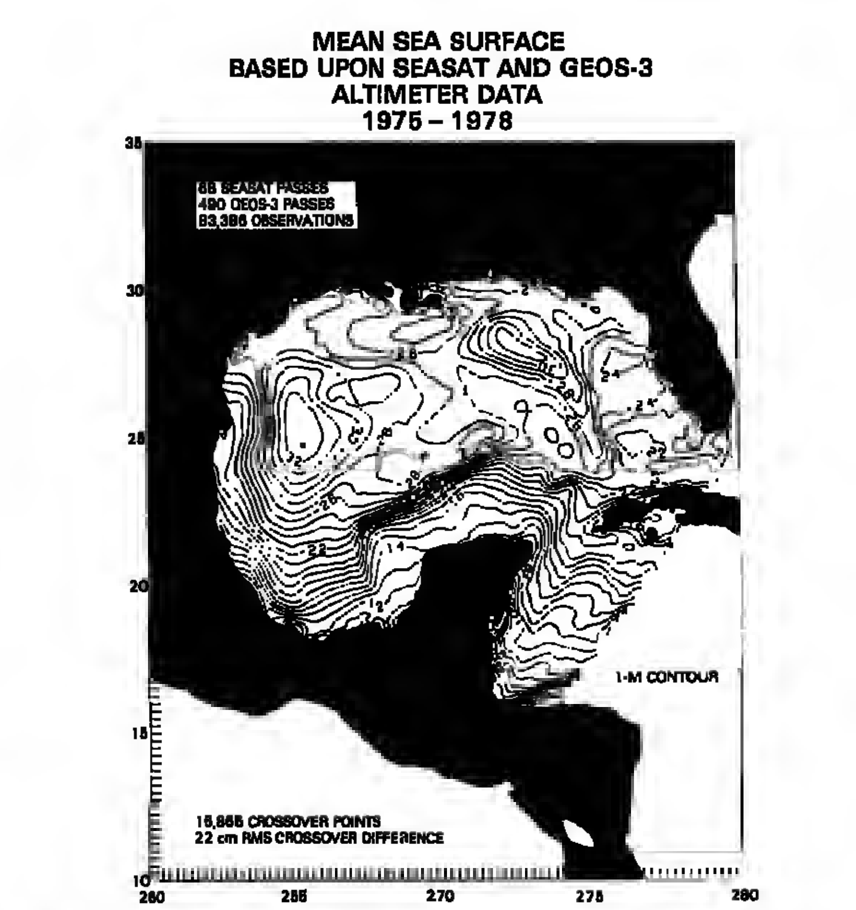

Fig. 1. Mean sea surface for the Gulf of Mexico based upon GEOS-3 and Seasat altimeter data of July-October 1978. The adjusted along-track data have been gridded on a 0.25° x 0.25° grid [*Marsh et al.*, 1984].

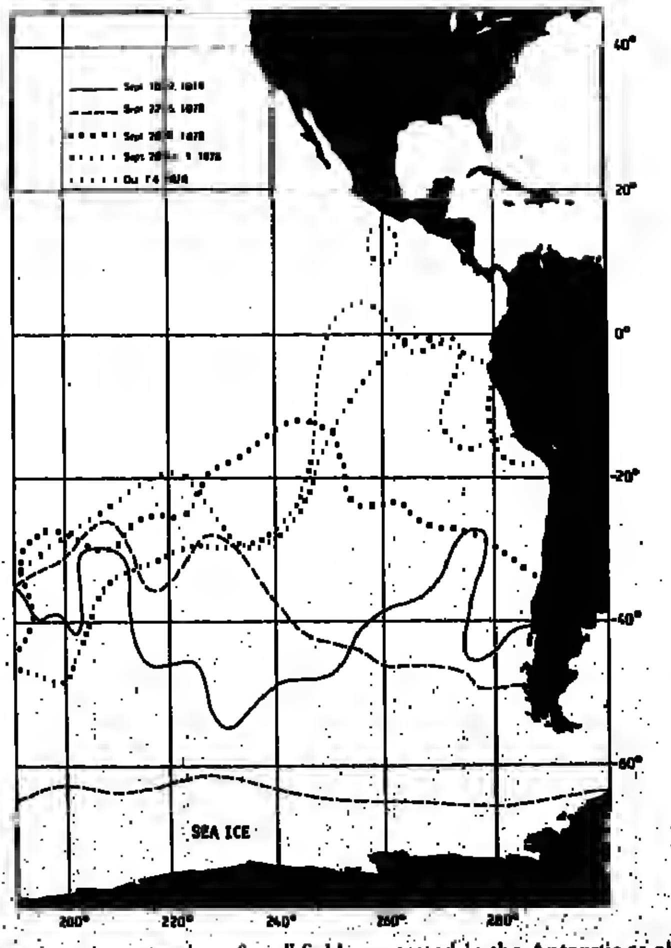

Fig. 2. Northward propagation of swell fields generated in the Antarctic as observed by the Seasat altimeter. Isopleths indicate the northernmost extent of swell greater than or equal to 3 m during the given 3-day periods [*Mognard*, 1984] (reprinted with permission, Crane, Russak & Co., New York).

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The Oceanography Report

Sifting Deposit.

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Lagrangian Studies of Deep Ocean Currents

T. Rossby

It is now more than 10 years since the first experiment using subsurface drifters (so-called Sofar floats) took place in the Mid-Ocean Dynamics Experiment (Mode). Since then they have been applied in a series of exploratory studies culminating in the Polymode Local Dynamics Experiment (LDE), and more recently along 55°W in a study of the North Atlantic subtropical gyre in a region well removed from the dynamics of western boundary regions. These neutrally buoyant instruments, which can be ballasted to drift with the waters at pressures up to 2000 dbars (meters), are tracked acoustically over long periods of time (months to years). Conceptually the floats may be thought of as large molecules, fluid parcels whose pathways and speeds are explicitly known. The structure of their trajectories often yields surprisingly detailed information on the horizontal structure of the velocity field. When used in clusters they can tell us much about the mean field and the dispersive properties of the region. This article provides a brief retrospective of what we have learned in the 10 years since their first application in Mode. We begin with a brief description of the Sofar float technology.

Tracking Sofar floats over great horizontal distances is possible thanks to a remarkable acoustic property of the ocean known as the deep ocean sound channel or Sofar (sound fixing and ranging) channel. This acoustic wave guide, well known to acousticians and submariners since World War II, owes its existence to the happy fact that the speed of sound is a strong and comparable function of oceanic pressures and temperatures. In the upper ocean the speed of sound decreases rapidly with depth due to the thermal stratification; in the deep, nearly isothermal waters the speed of sound increases with pressure. The minimum speed of sound, about 1000–1300 m deep in the subtropical oceans is the axis of a permanent acoustic waveguide such that under quiet listening conditions one can hear a 1-W sound source at 250 Hz at distances greater than 1000 km.

The first suggestion to use the Sofar channel to track neutrally buoyant drifters was made by H. Stommel in 1949 in a paper on horizontal diffusion. In 1966 M. J. Tucker and D. C. Webb conducted an encouraging test of long-range transmission using a lightweight piezoelectric transducer, and in October 1968 a neutrally buoyant float was tracked for 4 months. But it was another 3 years before floats could be put to use systematically.

Today's variety of float consists of an aluminum flotation tube, 11.5 m in diameter and 5.5 m in length, which also provides the housing for the battery pack and electronics. The transducer, a thin-walled tube 1.8 m long and of the same diameter, is open at one end and has a piezoelectric bender plate at the other. It is mounted end-to-end to the flotation tube.

Acoustic signals are transmitted every 8 hours; each signal consists of an 80-s FM pulse (1.5 Hz linear chirp) at 250 Hz. Besides giving a better signal-to-noise ratio than the previously used amplitude modulated system, the phase modulation allows the use of simple digital correlators for signal detection and time of arrival determination. The radiated power levels have increased approximately from 3 W to 8 W, permitting tracking ranges out to 2500 km depending on the float's depth in the sound channel and ambient noise conditions at the receiver site.

The floats are equipped with an active ballasting system to maintain a prescribed depth, and telemetry of pressure and temperature. They are powered to last in excess of 2 years [*Webb*, 1977]. The early development of the Sofar float program was greatly simplified by the existence of landbased hydrophones on Bermuda, the Bahamas, and Puerto Rico. Their availability reduced the risk and cost of the program by permitting us to concentrate on the major technological uncertainty: the float itself.

Tracking the floats is conceptually very simple: Given knowledge of the speed of sound in the oceans and the time of arrival of signals at two or more receivers, one can determine from the intercept of circles (known travel times) or hyperbolae (travel time differences) the position of a float to within a few kilometers. With the recent development of autonomous listening stations (ALS), which can be moored in the sound channel for a year at a time, Sofar float studies are no longer restricted to areas within range of land-based hydrophones. This has added great flexibility to their use.

There is no question that the most powerful attribute of drifters is the horizontal information that is so effortlessly provided—effortlessly in the sense that even a single instrument can suffice to lay bare the circular structure of a Gulf Stream Ring, show the path of the Gulf Stream as it is swept downstream, or reveal the constraints imposed on fluid motion by variable bathymetry. As they drift they in fact articulate specific pathways and rates of displacement of fluid parcels; information that cannot be obtained solely from the observed distributions of different water masses.

In what way would a tracer (or a potential anthropogenic pollutant) disperse, and how rapidly? The Sofar floats provide us with a natural tool to examine these kinds of questions. With an ensemble of trajectories one can start to construct statistical statements about mean flow and rates of dispersion and juxtapose these with classical water mass analyses. Let us attempt a simple illustration.

Between 1976 and 1980 we obtained nearly two dozen float trajectories at 700 m lasting 6 months or longer. They were set at various latitudes, mostly in the vicinity of 70°W. If one examines their position as a function of time one finds that the floats set north of 28°–29°N disperse to the west and north, become entrained into the Gulf Stream and are rapidly advected to the east. The ensemble of floats to the south of 28°N show evidence of a cyclonic circulation to the south and east.

In Figure 1 we show a sketch of the trajectories of floats at 700 m after they have been subjectively smoothed to remove mesoscale motions. It suggests that a tracer that is injected into the Gulf Stream recirculation system will be trapped and repeatedly recycled; it is not likely to be flushed to the south. We can compare this with the distribution of tritium (^{3}H) along 53°W, Figure 2. Note that at 700 m the ^{3}H does not penetrate south of 23°–30°N, and in the deep waters it is restricted to latitudes north of 30°N.

A simple 2-dimensional interpretation would suggest that the ^{3}H has diffused this far since it was injected into the oceans in the mid-60's. The circulation pattern inferred from the floats, on the other hand, indicate that the waters north of 28°N are trapped to the north thereof and subject to rapid recirculation, whereas waters to the south of 28°N are associated with a circulation on a much larger spatial scale and, hence, a longer time scale.

This comparison is, of course, incomplete and would be more effective if we could look at the source or inflow conditions to the east of the section. This has not been done. The point here is that even 2 dozen trajectories can provide valuable path and dispersion information. The idea of using floats as an integral part of modern water mass analysis is, however, still in its infancy.

The dispersion of the floats can be used to estimate eddy diffusivities. On time scales of the order of months, dispersion of floats is dominated by mesoscale eddy processes, especially in regions of high eddy kinetic energy. Moreover, the diffusivity is apparently linearly related to eddy kinetic energy over a wide range corresponding to an integral time scale of about 8 days. The physical basis for this relationship is unclear, but it certainly provides a simple means of parameterizing mesoscale eddy mixing in numerical studies. Dispersion tends to be isotropic when eddy kinetic energy levels are high, whereas in quieter regions such as the center of the subtropical gyre there is a clear tendency toward zonal dispersion.

On numerous occasions Sofar floats have exhibited astonishingly circular orbits with diameters ranging from a few kilometers to nearly 150 km. These trajectories reveal a class of oceanic motion that, apart from the ubiquitous Gulf Stream rings, was all but unknown 10 years ago. Spinning in either direction, these motions can be found in shallow as well as deep waters. And almost without exception their zonal motion is toward the west.

Figure 3 shows the trajectories of two Sofar floats (a third one is omitted for clarity) near 700 m depth spinning around a westward-migrating body of water until it appears to collide with the Bahamas escarpment (or a boundary current along it) and the floats escape. Hydrographic observations at the time the floats were set revealed a thin lens of somewhat diluted Mediterranean water about 600 m thick and 120 km in diameter.

Other observations of such lenses of Mediterranean water have since been made in the eastern Atlantic. Assuming a westward migration velocity of 3 cm s^{-1} from its region of probable formation, the "meddy," as it is sometimes referred to, must be at least 3 years old. With a mean period of revolution of 10 days, say, the lens must have made at least 100 revolutions since its genesis. Clearly the lenses are very stable, and as Figure 3 suggests, their demise may not be one of slow decay, but a sudden one due to changes in their environment, be it topographic "collisions" or their rupture by horizontal shear.

These lenses do not appear to have any atmospheric counterpart. What makes them particularly interesting is the suspicion that they may play an important role in the observed distribution of salt, oxygen, and other tracers in the ocean. Created in the east (it is not known how), they propagate zonally to the west and "deposit" the transported waters where they collapse. This suggests the possibility that observed distributions of water properties in some sense represent the probability density distribution of disintegration of these lenses and not solely a balance between a large-scale mean flow (to be determined) and eddy mixing, as is often assumed in diagnostic studies of ocean circulation.

Conservation statements of the form $d/dt\,(*) = 0$ are intrinsically Lagrangian concepts where the property denoted by the asterisk remains invariant under translation of the fluid. The above mentioned "meddy" is, of course, one example of fluid conservation. A corresponding dynamical test, namely the conservation of potential vorticity, has also been demonstrated.

Following a set of 10 Sofar floats for 2 months at 1300 m, *Price and Rossby* [1982] found that as the cluster moved north such that the local vertical component of planetary angular momentum increases, the cluster responds by turning in the opposite (or clockwise) direction so that its absolute angular momentum is conserved, and conversely so when they moved to the south (Figures 4*a* and 4*b*). For good numerical agreement it was found necessary to include vortex stretching caused by variable bathymetry.

Horizontal arrays of Sofar floats have been used effectively to produce synoptic analyses of the velocity field. In both Mode and the Polymode LDE the systematic combination of velocity measurements at one level and hydrographic surveys have been used to analyze the dynamic state and evolution of the mesoscale eddy field. This methodology works well, but the rapid dispersion of floats limits to a few weeks the time during which accurate synoptic maps of the stream function can be constructed. The longevity of the Sofar floats is of no help here; thus, for future studies of this kind there may be a need for a simple, low-cost Sofar float of medium range of the kind used in the French Tourbillon experiment [*Groupe Tourbillon*, 1983]. For a more detailed discussion of the above ideas the reader is encouraged to consult chapters 4 and 5 in *Robinson* [1983].

Sofar floats are now in use in four experiments in the North Atlantic: The URI-WHOI Line and Gulf Stream Recirculation Experiments, Dispersion Studies in Very Energetic Eddy Fields (WHOI), Topogulf (a French program), and a nascent British study of dispersion in very deep waters. The technology is mature and reliable. The inability to track the floats in real time, however, has handicapped experimental plans to use floats interactively (for example in hydrographic surveys.) This has stimulated a program called Relays (WHOI) to develop listening systems which are suspended down into the sound channel from drifting surface platforms. Tracking data can thus be relayed immediately to ARGOS (a satellite-based platform location and data collection system).

At present long-range float tracking is limited to oceans with permanent thermoclines where acoustic energy is trapped by refraction only. However, I believe it is possible to extend the technique to cold oceans with so-called half sound channels, i.e., where rays undergo surface reflection. For this to work, however, it is necessary to work at much lower frequencies such that the acoustic wavelength is long compared to the sea surface roughness. The way to do this would presumably be to reverse the entire procedure and place on continental slopes very low frequency sound sources powered from shore (in which case the acoustic power levels can be greatly increased). The floats listen and store the time of arrival information for later transmission to ARGOS at the end of its mission.

A version of this listening float, the Rafos (Sofar spelled backward) float, is currently undergoing trials in the Gulf Stream. It listens to moored Sofar floats, one of them south of Cape Hatteras and the other on the northern slope of the Bowditch seamount (Bermuda). Real-time tracking is obviously not possible. Rafos floats are also restricted to somewhat shorter tracking ranges than the Sofar floats, because, owing to their small size and weight, the floats cannot carry a vertical string of hydrophones, which would improve acoustic reception in the horizontal.

The Rafos float is an outgrowth of the development of the deep drifter, which is the same instrument minus the acoustic listening system. The deep drifter is intended to be used in clusters to obtain accurate estimates of subsurface and abyssal mean flows by ensemble averaging. The argument is simple: Continuous tracking of a float, like a continuous record from a current meter, does not improve statistical confidence of the record mean if it is not long compared to the gravest energy-containing frequencies. Since these are often of the order of a year we will be old men before we are finished!

The way to defeat this is of course by making many independent observations, but this is expensive; hence, a need for a simple, inexpensive drifter. When used in clusters they provide an ensemble of displacement vectors, each one a time integral of Lagrangian motion. Further, the spread of the ensemble of drift vectors provides valuable information on the dispersive properties of the field. The paucity, if not complete lack, of information on mean flows and dispersion in much of the world oceans is well known.

A recent development is the recognition that floats can be given isopycnal (constant sigma-t) properties. By increasing the compressibility of the float (by adding a spring-backed piston) to match that of seawater, changes in pressure cannot effect a change in buoyancy relative to the surrounding fluid. If the float can be given a small (preferably zero) coefficient of thermal expansion, such as with borosilicate glass (Pyrex), its density will not depend upon temperature. Hence, if the float is neutrally buoyant at some sigma-t it will remain there regardless of what the temperature (and salinity) is. This technique should be quite helpful in studies of dispersion and mixing across fronts. Because the in situ density gradient due to compressibility is no longer contributing to the stability of the float, the requirements for accurate ballasting are more severe than for conventional isobaric operation.

In summary, drifters have considerable conceptual overlap with modern water analysis (especially marine chronochemistry). It seems inevitable that the links between the two will become stronger in the coming years, as the need grows to distinguish between fluxes by the mean field, by eddy mixing, and by discrete eddies. Lagrangian techniques also appear to be a powerful tool in synoptic studies of local dynamical processes. What is perhaps not so obvious is that the neutrally buoyant float offers a platform for observing small-scale processes without the problems associated with advection past stationary platforms.

Indeed, with the ready availability of sophisticated yet low-powered microprocessors, one can foresee the development of a variety of "intelligent" drifters designed to monitor the internal wave field, chemical changes due to isentropic mixing, or listen to and observe the local ecosystem. Days, weeks, or months later they can surface and report their findings; these can then be related to the large-scale processes within which they were embedded.

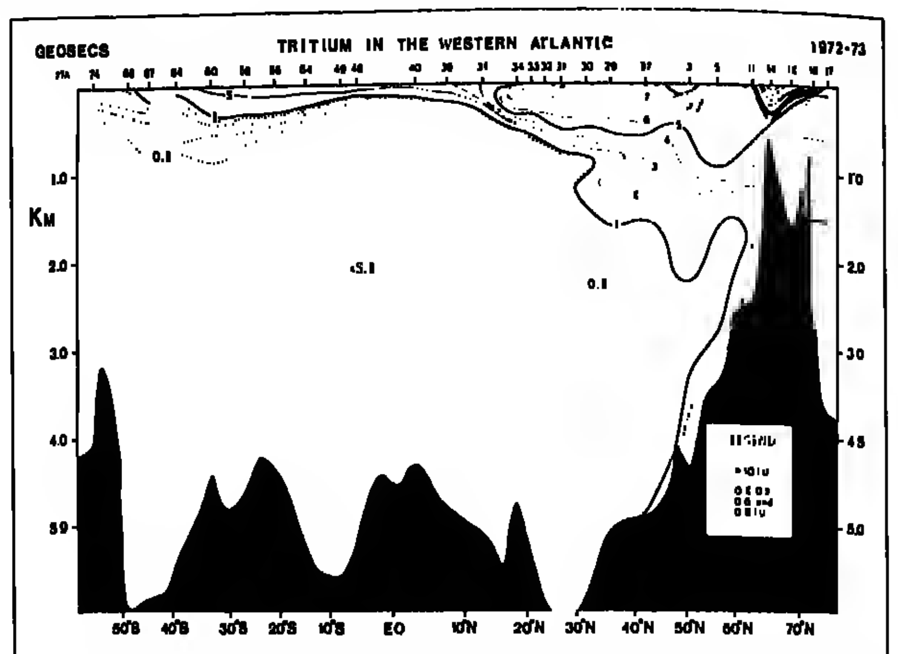

Fig. 2. Distribution of ^{3}H along a N-S section in the Western North Atlantic [*Ostlund et al.*, 1977].

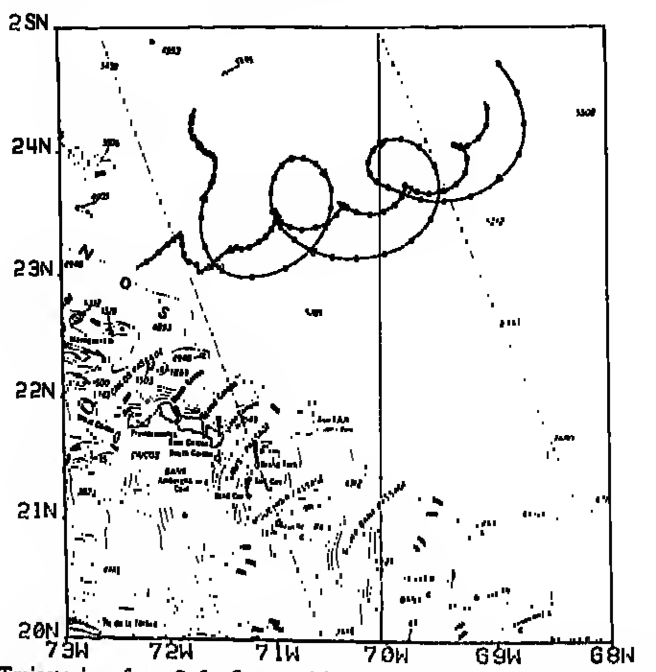

Fig. 3. Trajectories of two Sofar floats at 700 m orbiting around a common center of westward translation. The inner trajectory has a 10-day period, the outer one 17 days.

Fig. 1. Spaghetti plot of smoothed trajectories of Sofar floats at 700 m. Arrows are 100 days apart. Note the high velocity of floats caught in the Gulf Stream (from chapter 4, *Robinson* [1983], reprinted with permission, Springer-Verlag, New York).

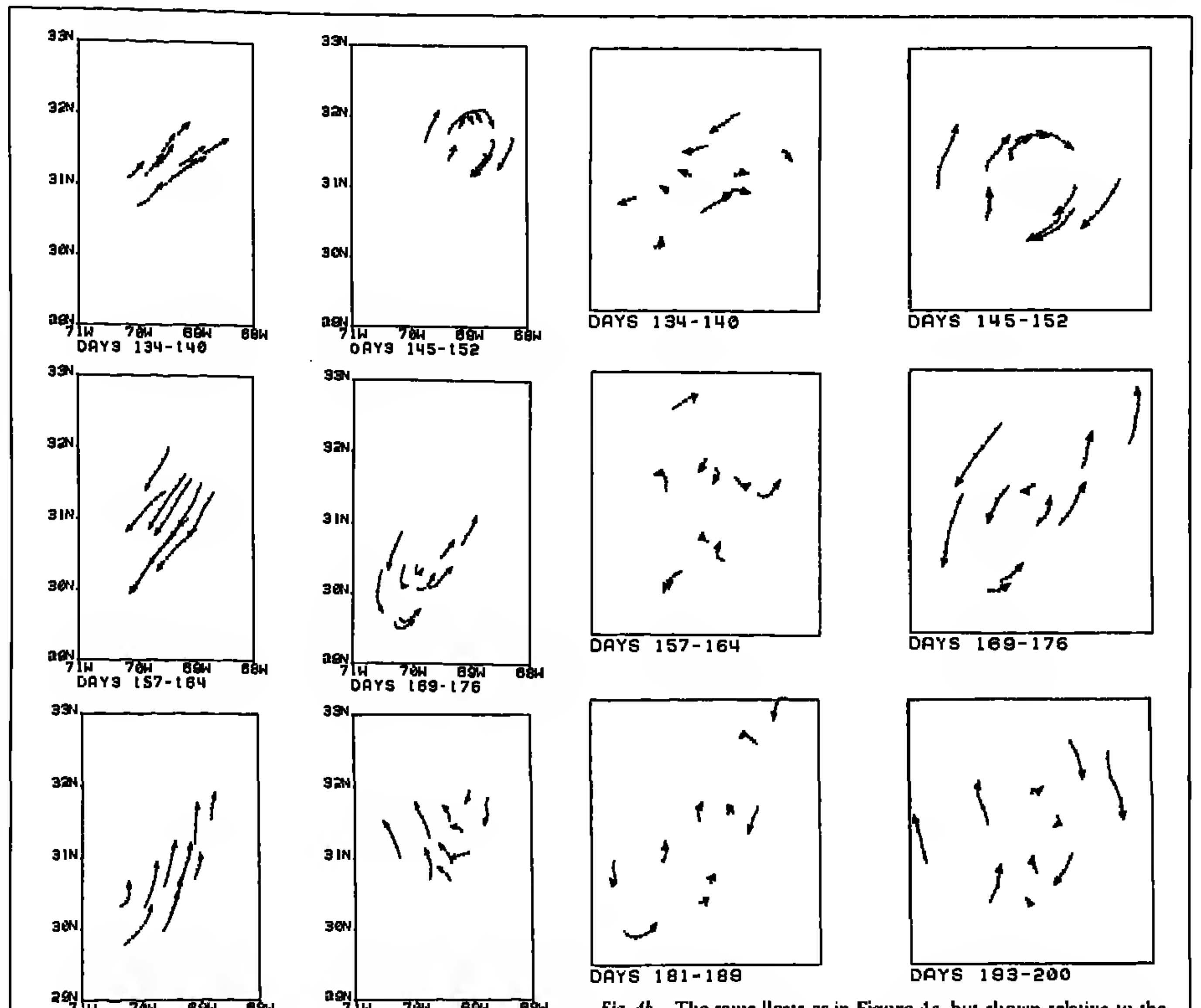

Fig. 4a. The geographical position of 10 floats at 1300 m in 12-day steps.

Fig. 4b. The same floats as in Figure 4*a*, but shown relative to the center of gravity of the cluster. Note the anticyclonic movement while the cluster is in the north, and the converse in the south [*Rossby*, 1982] (reprinted with permission, Springer-Verlag, New York).

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Transactions, American Geophysical Union

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Cover. Global mesoscale sea height variability measured by the Seasat altimeter, September 15 to October 10, 1978, when the satellite track repeated at a 3-day interval (figure from *Cheney et al.* [1983], cited in article by Mooers et al. on page 81, this issue).

Meeting Report

Quantifying Submarine Hydrothermal Fluxes

Many oceanographers believe that the chemical fluxes associated with deep sea hydrothermal processes are large and geochemically important, but quantifying these fluxes is proving difficult. Seawater-basalt exchange takes place in high-temperature hydrothermal systems at the very axis of seafloor spreading, as observed at the Galapagos Spreading Center [*Corliss et al.*, 1979], and the East Pacific Rise at 13°N and 21°N [*Michard et al.* 1982; *RISE Project Group*, 1980]. It also takes place in the lower temperature hydrothermal systems, which are ubiquitous on the flanks of mid-ocean ridges, until sedimentation, and void-filling in basalt, seal the hydrothermal systems at crustal ages between 10 and 80 m.y. [e.g., *Anderson et al.*, 1977].

Chemical fluxes associated with crustal water/rock reactions have been estimated in two ways. One involves using the heat balance to estimate the rate at which hydrothermal solution exit the crust, and taking the product of this number and change in chemical concentrations to get chemical fluxes. The composition of hydrothermal solutions exiting at the ridge crest is well known; solutions are depleted in Mg^{++} and $SO_4^{=}$, and enriched in Ca, alkalis, and heavy metals [e.g., *Edmond et al.*, 1979; *Mottl and Holland*, 1978]. However, the heat flux is poorly known, with current estimates ranging between 0.2–5 x 10^{19} cal per year (0.8–21 x 10^{19} J per year) [*Sleep et al.*, 1984; *Edmond*, 1981]. On the ridge flank, the opposite situation obtains. The convective heat flux is known to be about 5 x 10^{19} cal per year [*Anderson et al.*, 1977; *Williams and Von Herzen*, 1974], but almost nothing is known of the composition of the reacted seawater.

The alternative method of constraining hydrothermal fluxes comes from the complementary approach of studying crustal chemistry. The composition of unaltered crustal rocks is known from detailed studies of a few DSDP holes, and hydrothermal fluxes may be estimated from the crustal generation rate and the crustal chemistry of representative sections [*Hart and Staudigel*, 1982; *Thompson*, 1984]. This approach is bearing fruit, but has a limited applicability because of the limited availability of samples taken within the oceanic crust.

To consider these problems, the University of Rhode Island's Graduate School of Oceanography recently hosted a 1-day symposium, under the auspices of the Norman Watkins Lecture Series, on the topic, "Quantifying Submarine Hydrothermal Fluxes: Evidence From Different Perspectives." The lectures of the seven speakers were discussed by members of the audience from URI and her sister institutions in New York and New England.

Norman Sleep (Stanford) and William Jenkins (WHOI) discussed constraints on the axial heat flux from thermal modeling and the oceanic He isotope distribution, respectively. Sleep estimated the maximum axial convective heat flux as 2 x 10^{19} cal per year (determined from the product of the total crustal generation rate and the latent sensible heat loss per gram of crust [*Sleep et al.*, 1984]). He

Oceanography (*cont. on p. 87*)

News

No Olivine in the Mantle?

Perhaps the most impressive factors in D. L. Anderson's analysis of new physical models of the earth are contributions from the numerous disciplines of modern geophysics, including 3-dimensional seismological observations, high-pressure experiments, highly precise isotope analyses, and studies of other solar system bodies [*Science*, *223*, pp. 347–355, 1984].

The results? In short, there are the "ins" and the "outs." For example, the basalt-eclogite transition is back in fashion, whereas the notion of an olivine-rich deep mantle assemblage is no longer in fashion. This analogy is not to be construed as any return to old, preplate-tectonic concepts. Modern research, in the purest sense, is forcing "a reexamination of some long-held assumptions."

Anderson would not only ask to have the concept of the basalt-eclogite transition be revisited as a dominant crust-mantle parameter, but he provides insight to his suspicion of the validity of the olivine-spinel phase change and other olivine-related transitions as important boundaries in the transition zone. Thermal expansion and other thermally derived processes in the mantle (i.e., a hot, low-velocity zone) are suspect as well. So, therefore, the olivine-spinel transition is "out," as is the concept of a partial-melt, spherical shell, low-velocity zone from which basalts could be derived. Instead, "the buoyancy differential that drives mantle convection is provided by partial melting and the basalt-eclogite phase change rather than thermal expansion" and "the large density changes associated with phase changes and melting in the basalt-eclogite system may drive convection and be responsible for the chemical stratification of the mantle and the long-term isolation of geochemical reservoirs." The result is that an olivine-rich mantle concept would not be compatible.

Anderson's synthesis of observational and experimental data, trace element analyses, and the approximations and model functions required to fill the gaps of knowledge is a courageous, and, of course, controversial, attempt toward taking an imaginative look at all approaches to deriving a meaningful earth model. It may be argued that the new interpretations of this model are no better than those existing, because many of the advances in seismology and experimental research on which the model is based are too new. Considerably more data are needed to justify many of Anderson's conclusions, and some large knowledge gaps will not be filled soon. Anderson cannot be faulted, however, for lack of imagination nor for creating a set of ideas presented in a scholarly way. Anderson's model should stimulate a strong response; the response may be in the form of obtaining the needed data.—*PMB*

Radio Telescope Center Selected

Socorro, N. Mex., will be home for the operations center for the Very Long Baseline Array (VLBA) network of radio telescopes. The National Radio Astronomy Observatory (NRAO) selected Socorro because of its proximity to the Very Large Array (VLA), an existing system of 27 radio telescopes and will allow combined operation of the VLBA and the VLA. In addition, two of the proposed VLBA antennas will be nearby. With the proposed array of 10 radio telescopes—from Puerto Rico to Hawaii—astronomers will be able to probe the universe with a resolution 1000 times greater than any existing radio or optical telescope and 100 times that of the future Hubble Space Telescope.

The VLBA will be operated by NRAO as a national facility. NRAO is operated by Associated Universities, Inc., a consortium of nine member universities under contract with the National Science Foundation. The proposed funding increase for VLBA for fiscal 1985 (up 62.1% to $33.4 million) would go for construction of the array (*Eos*, February 14, 1984, p. 49).

Acid Rain Trends Summarized

In the northeastern United States, the acidity of precipitation has changed little in recent years, although the acidity is increasing in other regions. That's the latest word from a comprehensive review by the U.S. Geological Survey (USGS) of more than 200 published reports of acid rain research from the past 30 years. The report contributes to the controversy over whether increased sulfur emissions from Midwest powerplants increase the acidity of precipitation in the Northeast.

"When the results of the many individual studies are combined, they show that acidification of precipitation in the Northeast, which has the most damaging level of acidity on a regional basis, occurred primarily before the mid-1950's and has been largely stabilized since the mid-1960's," said John T. Turk, a research hydrologist at the USGS Denver office and author of the 18-page summary report.

Turk concluded that surface waters in lakes and streams in the Northeast follow a pattern of acidification similar to that of precipitation. The acidification of surface waters occurred before the mid-to-late 1960's; since then, some waters have not acidified further, and other streams show a slight recovery.

Trends in the acidity of precipitation in the southeastern and western parts of the country is far less certain. "In the southeastern United States, the available data show that precipitation is more acidic than would be expected for sites unaffected by manmade emissions," Turk said. "In addition, a comparison of recent precipitation data with the meager historical data suggests an increase in acidification of precipitation since the 1950's." Turk found, however, that most of the available data are ambiguous as to whether acidification of surface water has occurred in the southeast.

Copies of *An Evaluation of Trends in the Acidity of Precipitation and the Related Acidification of Surface Water in North America* (USGS Water Supply Paper 2249) are available for $2.75 each from the Branch of Distribution, Text Products Sections, USGS, 604 S. Pickett St., Alexandria, VA 22304.

In Congress

Upcoming Hearings

The following hearings have been tentatively scheduled for the coming weeks by the Senate. Dates and times should be verified with the committee or subcommittee holding the hearing or markup; all offices on Capitol Hill may be reached by telephoning 202-224-3121.

March 7, March 13, March 14: Clean Air Act (P.L. 95–95) amendments (S. 768) markup by the Senate Environment and Public Works Committee. Dirksen Building, Room SD-406, 10 A.M.

March 19: National Oceanic and Atmospheric Administration fiscal 1985 budget hearings by the Commerce, Justice, State, Judiciary, and Related Agencies Subcommittee of the Senate Appropriations Committee. Capitol, Room S-146, 2 P.M.—*BTR*

Geophysical Events

Volcanic Events

Campi Flegrei (Italy): Uplift and seismicity in the caldera since mid 1982.
Etna (Sicily): Incandescent tephra from central crater; seismicity.
Kilauea (Hawaii): 13th–15th major phases of East Rift Zone eruption include lava fountains to 300 m and temperatures to 1147°C.
Mt. St. Helens (Washington): Deformation and seismicity, then new lobe.
Veniaminof (Alaska): lava fountains and flow continue.
Pavlof (Alaska): Plumes on satellite imagery harmonic tremor.
Piton de la Fournaise (Réunion Is.): Second phase of lava emission.
Sakurajima (Japan): 1983 explosions and ashfalls tabulated.
Kusatsu-Shirane (Japan): 1983 activity summarized.
Rabaul (New Britain): Marked increase in unrest.
Manam (Bismarck Sea): Strombolian activity; explosion cloud to 3.5 km.
Langila (New Britain): Vulcanian explosions; ashfalls on coast.
Bagana (Solomon Islands): Two active lava flows.
Erebus (Antarctica): Seismicity normal; SO_2 flux measured.
Atmospheric Effects: El Chichón cloud persists; lidar data to north pole.

Campi Flegrei, S *Italy (40.83°N, 14.14°E)*.

The following report is from Giuseppe Luongo, Roberto Scandone, and Franco Barberi: "Campi Flegrei (Phlegraean Fields) is a large caldera some 12–14 km across, located roughly 25 km W of Vesuvius and 15 km WSW of the city of Naples. The caldera formed after a huge eruption 35,000 years ago that produced 80 km³ of dense rock. Several other eruptions of decreasing intensity have occurred since then. In the past 10,800 years at least 22 different centers are recognizable. The last eruption occurred in 1538.

"Campi Flegrei has been the site of slow vertical movements since at least Roman times. A slow subsidence had occurred since the last eruption in 1538. An uplift that was observed in 1970 continued until 1972 without significant seismic activity. The inferred maximum uplift with respect to previous levelings was 170 cm. Slow oscillations of the ground were observed between 1972 and 1982. The oscillation had an annual period with a range of about 10–15 cm per year in the zone of maximum uplift. Since the summer of 1982, the oscillation has not reversed as in previous years. The overall uplift amounted to 110 cm between January 1982 and December 1983 in the zone of maximum movement, within the town of Pozzuoli in the center of the caldera (Figure 1). Repeated leveling surveys in the area have given evidence of an area of uplift of about 6 km radius with a fairly circular symmetry. Horizontal deformation data give evidence of a maximum extension of about 40 cm over 4 km, nearly coincident with the area of maximum vertical uplift.

"In November 1982, moderate seismic activity was observed by the permanent seismic network, which has been operating since 1972. The level of activity was slightly above the microseismic activity in the area. In January 1983, public officials were notified of the anomalous trend of the phenomenon and of the possibility of an increasing seismic and volcanic hazard. In March a distinct increase in seismic activity was observed with the first magnitude 3 earthquake. Since then, ground uplift has continued with a velocity that reached 5 mm per day during October. After October, oscillations in the rate of uplift were observed, with a range between 1 and 4 mm per day. The seismic activity increased following a trend similar to that of the uplift velocity (Figure 2). A magnitude 4 earthquake occurred on October 4 when the rate of uplift reached 5 mm per day. This earthquake caused some building collapses (without injuries) in the town of Pozzuoli. Downtown Pozzuoli was evacuated after this event due to the concern for the increasing seismic hazard. The main part of the town is built of old brick houses which were increasingly affected by the continuous seismic activity. On October 13, 1983, a seismic swarm of some 250 shocks occurred in 5 hours. The maximum magnitude was 3.0.

"The people evacuated from Pozzuoli were temporarily resettled in the resort areas surrounding Campi Flegrei. A new settlement has already been planned on the border of the more vulnerable area. The choice of the location of this settlement was made by public authorities in order to minimize the social consequences of evacuating people from their residences. The new settlement is relatively safe from a seismic point of view but is not safe from a maximum probable volcanic event.

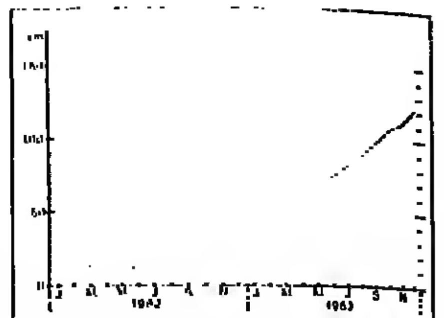

Fig. 1. Uplift as measured by the tide gauge at Pozzuoli, 1982–1983.

"The earthquakes of higher magnitude are mainly confined within a restricted area under the Solfatara crater (Figure 3). They are offset with respect to the area of maximum uplift, and their mean depth is about 3 km. Preliminary focal mechanisms indicate a predominantly tensile field in this area. The data on temporal distribution of earthquakes indicate a swarm-type character of the events. The event of maximum magnitude (4) occurred October 4, 1983, and its epicenter was in the Solfatara area. A close correlation seems to exist between the velocity of uplift and the seismic activity. The more energetic earthquakes seem to coincide with the higher rates of uplift (4–5 mm per day). The shallow character of the seismic activity does not give any evidence of a zone of anomalous propagation of S waves.

"Since April 1983, radon measurements have been made in water wells located in the area. The data are still too preliminary to infer any model. We await a prolonged period of measurements to infer what may be the seasonal trend. Temperatures of the Solfatara fumaroles are also continuously monitored. Gas monitoring of the fumaroles of Solfatara is carried out by several teams from the universities of Palermo, Pisa, and Florence, both by continuous measurement and by periodic sampling. Preliminary data seem to indicate an increase in the energy flux supplied to the deep water table located at 1.2 km depth by the geothermal wells. Two detailed surveys of the helium content of the ground have been performed by a team from the University of Rome. Order of magnitude variations have been detected in a large area NW of the town of Pozzuoli.

"The permanent surveillance network operating in the area comprises measurements of ground deformation and seismic activity, and monitoring of gas content and temperatures of fumaroles. Vertical ground deformation is measured by a repeated leveling of a permanent network and is also checked daily by a tide gauge in Pozzuoli harbor. The permanent seismic network operating in the area (Figure 3) is composed of 22 vertical seismometers, 15 of which are cable connected to a central point in Naples. A seismic explosion campaign has been planned in the Gulf of Pozzuoli to provide information on the deeper structure of the area. In cooperation with University of Wisconsin seismologists, a temporary network of 10 three-component stations with high dynamic range has been deployed in the area and will operate for some months."

Information contacts: Giuseppe Luongo and Roberto Scandone, Osservatorio Vesuviano, Largo S. Marcellino 10, 80138 Napoli, Italy; Franco Barberi, Dipartimento di Scienze della Terra, Via S. Maria 53, Pisa, Italy.

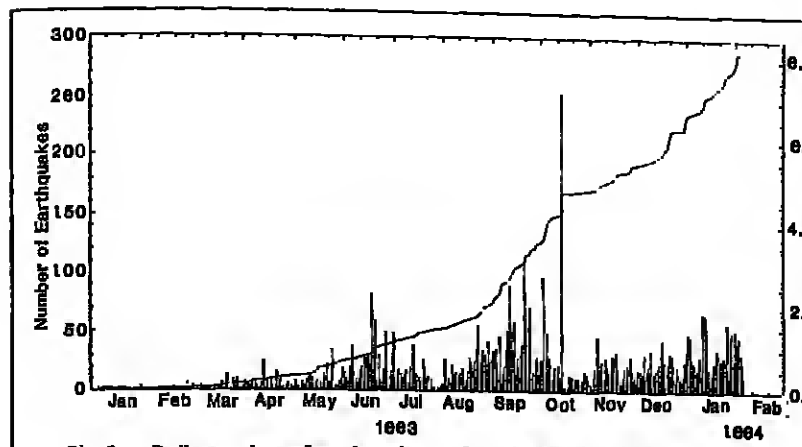

Fig. 2. Daily number of earthquakes at Campi Flegrei (vertical lines) and cumulative strain release (curve), January 1983 to January 1984.

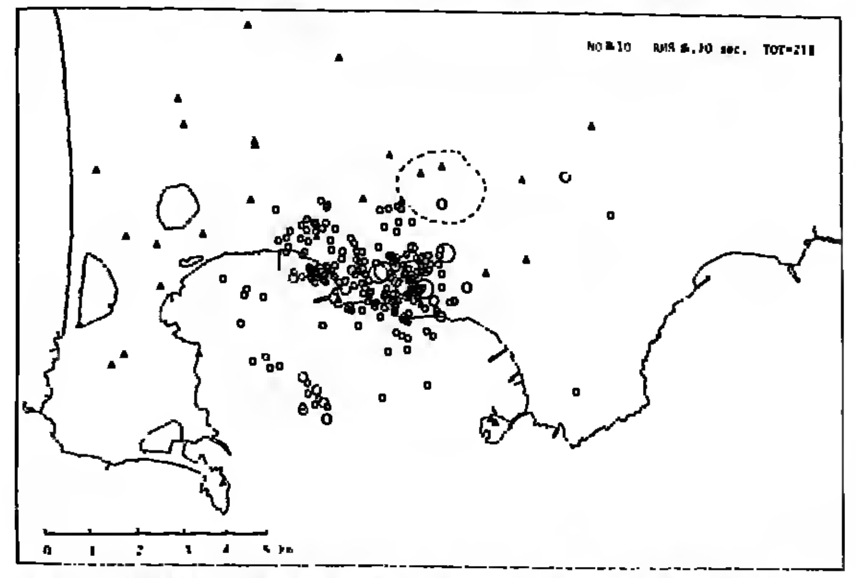

Fig. 3. Distribution of the best-located earthquakes (circles) and positions of seismic stations (triangles).

Rabaul Caldera, *New Britain Island, Papua New Guinea (4.27°S, 152.20°E)*.

This report is from P. Lowenstein: "There was a marked increase in the amount of unrest in Rabaul Caldera during January, with a total of 8372 volcanic earthquakes recorded, an increase of 1255 over the December total (see last month's Bulletin).

"A major seismic crisis took place on January 15 when 942 earthquakes occurred, including several strongly felt events. The maximum magnitude earthquake (ML 4.0) was accompanied by underground rumbling sounds. This crisis was accompanied by a maximum tilt change of 32.5 microradians at Rapindik tilt station and a lateral intrusion of about 0.3×10^6 m³ of magma at a depth of 0.9–1.1 km. This resulted in a shift of the center of maximum uplift of about 1 km to the NW of its previous location, bringing it closer to Rapindik than to Tavurvur.

"The overall distribution of earthquakes in January was similar to that in December, with high concentrations on the NE (Greet Harbour) and W (Keravia Bay) sides of the harbor. Local concentrations of events also occurred along the Rapindik NE-SW fault line after the seismic crisis on January 15.

"Steady inflation of the Keravia Bay and Greet Harbour magma reservoirs continued throughout the month. The lateral intrusion of magma under Greet Harbour resulted in a maximum uplift of 6 cm in Greet Harbour and a vertical displacement of 3 cm along the Rapindik Fault.

"As a result of the increased activity in January, a warning was issued to the authorities to the effect that the eruption, which was previously thought to be only a possibility when the stage 2 volcanic alert was declared on October 29, was now much more likely to occur within the next few months."

Information contact: P. Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Earthquakes

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225.

Earthquakes

Date	Time, UT	Magnitude	Latitude	Longitude	Depth of Focus	Region
Jan. 1	0604	6.5 mb	33.40°N	137.32°E	374 km	S of Honshu, Japan
Jan. 8	1524	6.6 Ms	2.82°S	118.89°E	shallow	W Sulawesi, Indonesia

Meteoritic Events

Fireballs: Austria (2); Austria-Czechoslovakia; N Central USA—S Central Canada; Florida, Pennsylvania-New Jersey, Pennsylvania, USA

This is a summary of *SEAN Bulletin*, 9(1), January 31, 1984, a publication of the Smithsonian Institution's Scientific Event Alert Network. The entire Rabaul article is included; the Campi Flegrei and earthquake reports are excerpts. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. For the microfiche, order document E84-002 at $2.50 (U.S.) from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For the paper reprint, order *SEAN Bulletin* (giving volume and issue numbers and issue date) through AGU Separates at the above address; the price is $3.50 for one copy of each issue number for those who do not have a deposit account, $2 for those who do; additional copies of each issue number are $1. Subscriptions to *SEAN Bulletin* are available from AGU Fulfillment at the above address; the price is $18 for 12 monthly issues mailed to a U.S. address, $26 if mailed elsewhere, and must be prepaid.

Correction

On p. 66 of the Feb. 21, 1984, issue of *Eos*, the paragraph in column 2 under *Other Awards* headed "Robert E. Horton Medal" should have appeared at the bottom of column 1, just before the section headed "Robert E. Horton Research Grant."

Books

Negev: Land, Water, and Life in a Desert Environment

Daniel Hillel, Praeger, New York, xx + 270 pp., 1982, $32.95.

Reviewed by William Back

In view of the continuing increased concern about the extreme fragility of deserts and desert margins, *Negev* provides a timely discussion of land-use practices compatible with the often conflicting goals of preservation and development. The success of agricultural and hydrologic experiments in the Negev desert of Israel offers hope to the large percentage of the world's population that lives with an unacceptably low quality of life in desert margins. Deserts are the one remaining type of open space that, with proper use, has the potential for alleviating the misery often associated with expanding population.

In addition to the science in the book, the author repeatedly reinforces the concept that "western civilization is inextricably bound to the Negev and its environs, from which it has drawn, via its desert-born religions—Judaism, Christianity, and Islam—many of the mores and concepts, and much of the imagery and love of the desert, including man's relation to nature and to 'God'." Deserts often are erroneously perceived to be areas of no water: in reality, these are areas in which a little rainfall occurs sporadically and unpredictably over time. This meager water supply can be meticulously garnered to produce nutritious crops and forage.

Daniel Hillel, the internationally recognized soil physicist, was one of the original 12 founders of the pioneer settlement of Kibbutz Sdeh-Boker in 1951. Much of their early work was to study the methodology that early civilizations used to obtain water, to repeat their techniques, and to attempt to improve them. The author develops a strong archeological and historical theme about use of water from the time of the earliest people of the Negev up to the recent, sophisticated techniques of water management.

The main guides that he and his colleagues had for the Negev in the early days were the Bible and *The Wilderness of Zin* written by two British archeologists, C. L. Wooley and T. E. Lawrence, the latter who was to become the famed "Lawrence of Arabia." Nelson Glueck, whose book *Rivers in the Desert: A History of the Negev* was to come later (1959), tells of observing the efforts of Hillel and the other young pioneers in locating and refurbishing the ancient cisterns. Sdeh-Boker has now become a major tourist and cultural center (it is the location of the Institute for Desert Research, affiliated with the Ben-Gurion University of the Negev) and its success is due in part to Prime Minister Ben-Gurion's decision to resign from government and become part of this pioneering effort.

This extremely well written, entertaining book contains flashes of humor. It reads like a novel and is to a large extent autobiographical. The author has the uncommon talent to weave anecdotes into scientific facts and interpretation. The semitechnical style of writing with minimal references, and the scrapbook nature of the photographs add readability and poignancy to the book. The first part (66 pages) is a perceptive description of the ecology of deserts that includes discussions of water, soil, vegetation, ecosystem, animals, and man's relation to the desert. The second part of the book relies heavily on the author's scientific work and personal experiences that are used to describe these elements within the context of the Negev, somewhat as a case study but, perhaps, more as a microcosm of deserts worldwide.

Another fascinating example of the relationship between archeology and hydrology, in addition to the author's comments on reconstruction and importance of the cisterns, is the explanation of the countless heaps, mounds, and strips of gravel found on many hillsides covering scores of square kilometers that are commonly arranged to form regular geometric patterns. Previous speculations were (1) that the gravel mounds supported grapevines rooted under them and that the heat emission from the dark gravel hastened the ripening of the grapes; (2) that the gravel mounds were "aerial wells" designed to condense dew during the night to irrigate the roots of the grapevines; and (3) that the mounds were built to increase the rate of erosion from the hillsides to hasten the deposition of soil in the bottom-land terraces.

Actually, the mounds and ridges are an inadvertent artifact with no utilitarian value, but merely represent the accumulation of gravel that the early people cleared from the surface. Hillel's personal research demonstrated that, where the gravel pavement is removed, the unstable, loess-like soil slakes down to form a surface seal that markedly re-

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swell plus wind waves in fully developed seas. Monthly global maps of wind, significant wave height, and minimum swell from Seasat show not only the expected zonal patterns due to the trade winds and other major wind systems but also wind and wave features on scales as small as 1000 km. Winds and sea states were highest in the Southern Ocean, and the local maxima migrated eastward from the Atlantic to the Indian Ocean and finally into the Pacific during the summer of 1978. Using successive 3-day maps, swell fields have been tracked from their initial formation in the Southern Ocean northward through the Pacific toward North America (Figure 2).

Amplitudes and phases of ocean tidal components can be recovered with satellite altimeter data. The amplitude and phase of the M_2 tide in the Indian Ocean were obtained from a 2-dimensional, space-time, least squares harmonic analysis of the last month of the collinear Seasat data, Figure 3. There are four interacting amphidromic points surrounding a large area of maximum amplitude and stationary phase. This solution shows an enhancement of 10 to 20 cm in the maximum amplitude in the middle of the ocean compared with most models. Comparisons with the Schwiderski model indicate a shift northward for the amphidromic point near Australia and a southward shift for the one near Madagascar.

Ocean Circulation and Variability

Mesoscale eddies (scales of 50 to several hundred kilometers) occur in all oceans and are responsible for much of the horizontal mixing. The most intense eddies are associated with western boundary currents and other concentrated flows. Eddies may alter the amplitude of the sea surface by as much as 1 m. The meandering of intense currents, which generate many of the eddies, is considered part of the total eddy field.

Many of the altimetric techniques developed for observing sea height variability due to eddies are independent of orbit and geoid error. The method of collinear differences can be used for the last 25 days of the Seasat mission when the ground track was repeated within 2 km every 3 days. Mesoscale variability can be observed in those repeated profiles since the geoid is constant in time. Meandering currents and migrating eddies appear as wave-like signals propagating through the altimeter profiles. A global map of mesoscale variability compiled from all the Seasat collinear data (cover) shows the largest variability associated with five major current systems: the Gulf Stream, Kuroshio, Agulhas, Antarctic Circumpolar, and the Falkland/Brazil confluence. As expected, there is a marked contrast between high energy in the western parts of ocean basins and low energy in the east. Several areas such as the Eastern Pacific and South Atlantic are remarkably quiet with rms variability of only 1–2 cm. Because of the existence of these vast, low-energy regions, the North Equatorial Current systems in both the Pacific and Atlantic appear as zonal variability maxima. The relationship of this variability to bottom topography in the Southern Ocean can be interpreted in a manner consistent with theoretical concepts. For example, the generation of anticyclonic eddies is suggested downstream of the Macquarie Ridge.

Using this collinear data set, the wavenumber spectra of mesoscale variability were found to be a function of energy level. In high-energy areas close to major current systems, most of the energy is at wavelengths greater than 250 km. The spectrum follows a k^{-5} dependence as predicted by geostrophic turbulence theory. In low-energy areas, the spectrum follows a k^{-1} dependence from 100 to 1000 km, not significantly different from predictions of an atmospheric forcing model.

The collinear method can also be applied to the GEOS-3 altimeter data in the western North Atlantic where the data are particularly dense. Eddy kinetic energy computed from 3.5 years of GEOS-3 data (Figure 4) shows maxima of 1000–2000 $cm^2 s^{-2}$ in the Loop Current and Gulf Stream meander and ring region, with minimum values of approximately 200 $cm^2 s^{-2}$ toward mid-ocean, consistent with recent results from satellite-tracked drifting buoys. A significant difference between the altimetric map and those derived previously from ship drift data is the absence of high variability in the Gulf Stream along the coast. This graphically demonstrates that the altimeter is able to determine the energy associated with eddying motions (temporal variability) uncontaminated by contributions from strong horizontal gradients (spatial variability).

Alternatively, the gravitational signal can be removed directly by subtracting a detailed geoid model, such as the 5' x 5' GSFC gravimetric geoid for the western North Atlantic. Thus, the Gulf Stream and its rings can be observed in individual passes of altimeter data, and near-synoptic maps of the Gulf Stream can be produced. Similarly, the geoid can be removed from a regional surface computed from a grid of altimeter data. This application was demonstrated using only two weeks of Seasat altimeter data. The resulting residual maps show the 1-m dynamic height change of the Gulf Stream and several warm and cold core rings. This technique could be used during the GEOSAT mission to monitor monthly the Gulf Stream system. A final method for eddy detection is to use a long-term altimeter surface as a reference to locate ring anomalies in individual profiles. A mean sea surface generated from 3.5 years of GEOS-3 data plus 3 months of Seasat data has been successfully used for locating cold core eddies in the Sargasso Sea.

Several groups have addressed the problem of determining global ocean circulation using existing altimeter data and global geoid models. Although present geoid models are known to be relatively inaccurate at short and intermediate wavelengths (a few hundred to a few thousand kilometers), the longer wavelengths are very well determined from tracking of numerous earth-orbiting satellites. Recent Goddard Earth Models (such as GEM-L2 and PGS-S4) are probably accurate to 10 cm at wavelengths greater than 10,000 km. Since this is comparable to the scale of most ocean basins, these geoid models might be used to determine the gyre-scale flows.

In the initial computation of the mean altimetric surface, the radial orbit error (which for Seasat and GEOS-3 is of the order of 1 m), must be treated. However, solutions have been generated which reproduce some features of dynamic topography maps based upon hydrographic data. Each one treats the orbit error in a different way. In the first case a global altimetric surface was computed from 1.5 years of GEOS-3 data combined with the 3-month Seasat data set. With such a large quantity of altimeter data over a relatively long period, much of the radial error was probably removed through averaging. When this surface is differenced with the PGS-S4 geoid, a model developed especially for Seasat, gyre-scale features with the proper sense of flow are obtained (Figure 5). A global surface was also computed from only three days of Seasat altimeter data from which a Fourier series representation of the radial orbit error was removed through an analysis of crossover differences (where ascending and descending ground tracks intersect), together with the along-track altimeter data. A third surface was determined from a spherical harmonic analysis of the differences between the GEM-9 geoid and a 3-month Seasat altimeter surface of the Pacific. All three of these surfaces show similar gyre-scale features, a remarkable result considering the magnitude of the present altimetric and geoidal errors.

Fig. 4. Eddy kinetic energy computed from GEOS-3 altimeter over a period of 3.5 years by the collinear method for the Gulf Stream region [Douglas et al., 1983].

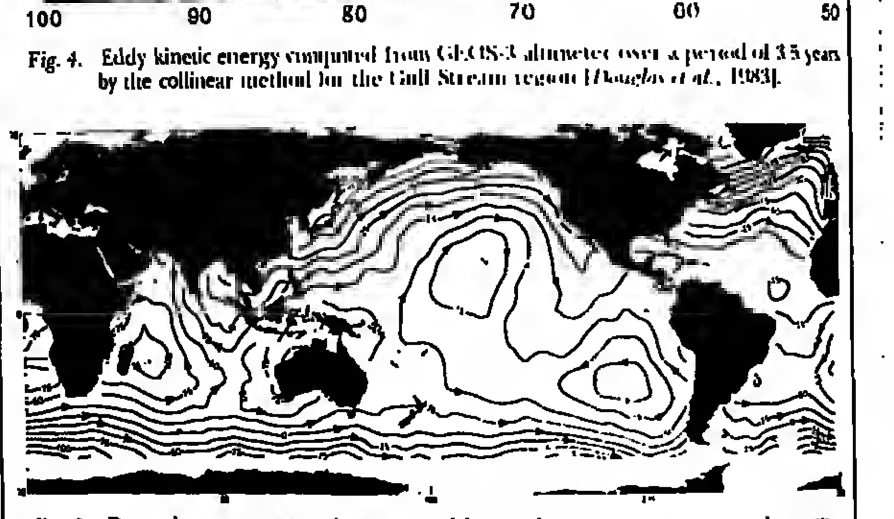

Fig. 5. Dynamic ocean topography generated from a long-term mean sea surface consisting of 1.5 years of GEOS-3 and three months of Seasat altimeter data for the Gulf Stream region. A global geoid model (PGS-S4) was subtracted from the altimetric surface to remove the contribution of gravity gradients [Cheney and Marsh, 1982].

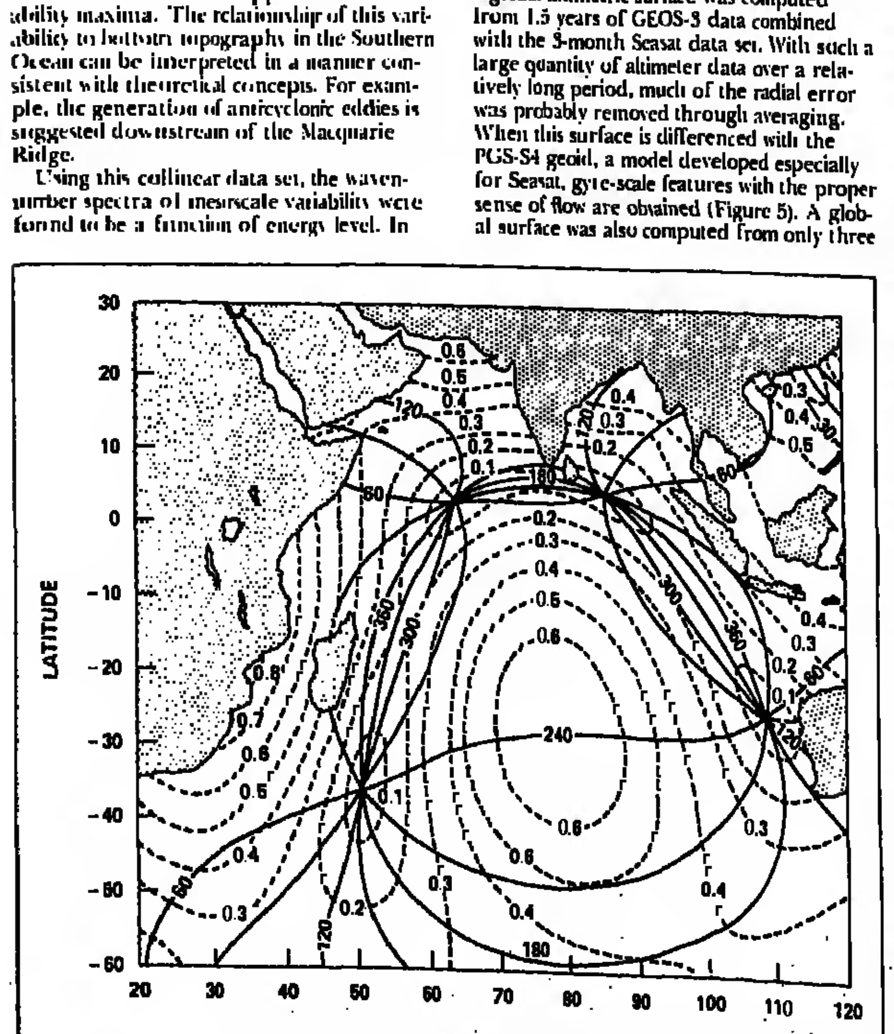

Fig. 3. Map of the M_2 oceanic tide solution for the Indian Ocean computed from Seasat altimeter data; cotidal lines (solid lines) in degrees; corange lines (broken lines) in meters [Mazzega, 1983] (reprinted with permission, Macmillan Journals Ltd., Washington, D. C.).

Ocean Models

A quasi-geostrophic, statistical-dynamical model has been used to simulate a satellite altimetric mission using the POLYMODE data set. The net improvement of ocean predictions achieved by 4-dimensional data assimilation of altimetric data, in addition to in situ observations, through optimal estimation theory, was demonstrated for hypothetical satellite tracks. Satellite altimetry can be further used to develop the correlation functions needed on a global basis to specify the error model for this method.

Eddy-resolving general ocean circulation models demonstrate the spin-up of an oceanic gyre by steady wind forcing and the generation of eddies by various hydrodynamic instabilities. The models reach a dynamical equilibrium between the mean and fluctuating flows, whose statistics show reasonable agreement with observations. These results suggest productive simulations could be performed in advance of an altimetric mission to determine whether eddy generation processes could be tracked by satellite altimetry. Also, statistics determined from altimetry could be used to validate the models.

A two-layered, semi-enclosed basin (Gulf of Mexico) model simulated that the eddy-shedding process could be studied by satellite altimetry. One to two eddies are shed per year, with horizontal scales of 50 to 350 km and dynamic height amplitudes of 75 cm. Seasat collinear passes have produced altimetric signatures consistent with model predictions. An equatorial reduced gravity wave model driven with slowly varying wind forcing has demonstrated the significant, wind-driven circulation events which propagate along the equatorial waveguide; e.g., those which lead to El Niño over the course of a few months. Satellite altimetry may contribute to studying this problem, and this model seems promising for sensitivity testing of the equatorial oceanic response to the quality of the atmospheric forcing determined from conventional wind analyses versus "unconventional" satellite wind data sources. A two-layered, global scale, coarse resolution (1° x 1°), hydro/thermodynamic general ocean circulation model is being developed by the Naval Ocean Research and Development Activity for operational use at the Fleet Numerical Oceanography Center. A preliminary, one-layered version yields an estimate of the seasonal mean dynamic topography which can be related to that determined by satellite altimetry.

Geology, Bathymetry and Ice Mapping

Bathymetric features, including the mid-ocean ridges, trenches, fracture zones, plateaus, and seamounts all produce corresponding features in the marine geoid as observed by satellite altimetry. The larger features, for example the Pacific trenches, are easily identified by inspection of the contour maps of the mean sea surface. Geoid features of a few tens of centimeters corresponding to smaller bathymetric features are sometimes difficult to identify. Using a matched filter for seamount detection, three uncharted seamounts have been detected in the western Pacific, and the geoid amplitude and degree of isostatic compensation for 14 of the Musician seamounts have been estimated.

Over the Musician seamounts, bathymetry has been predicted to better than 500 m. A mean sea surface has been high-pass filtered to emphasize those spectral components that correlate with seafloor topography and crustal structure. Several major and apparently new features have been revealed. For example, the Louisville Ridge appears to be a continuous series of short, echelon-ridge segments or seamount pairs. The region southeast of Valarie Guyot shows no topographic anomaly.

High-resolution geoid gradient maps of the South Pacific based upon a combination of the GEOS-3 and Seasat altimeter data have been constructed. Altimeter crossover height discrepancies associated with long wavelength radial orbit error were suppressed by taking the along-track derivatives of the ascending and descending passes. These geoid slopes were then rotated into the latitude-longitude reference frame and the north and east components of the geoid gradient were computed. In this region of the South Pacific, there are a number of 5° x 5° areas without any depth soundings whereas altimetric coverage of this area is relatively dense. Consequently, many previously undetected features appear on the maps. For example, 72 uncharted seamounts having geoid expressions greater than or equal to Easter Island's expression have been revealed. The dominant features, however, are the large age-offset fracture zones (FZ's) such as the Eltanin and Udintsev FZ's. The Eltanin FZ is connected to the Louisville Ridge; combined, they produce a continuous geoid signature across most of the South Pacific. This supports the hypothesis of D. Hayes and J. Ewing that the Louisville Ridge is the northwest extension of the Eltanin FZ.

Using digital enhancement techniques to analyze 1° x 1° gravity anomalies, features in the gravity field with amplitudes greater than 5–15 mGal and wavelengths greater than 50-

Article (cont.)

100 km have been resolved. In the Indo-Atlantic basin, where sparse data coverage has limited previous tectonic studies, bathymetric features such as trenches, ridges, fracture zones and seamounts are clearly visible.

Seasat also tracked areas of smooth terrain including deserts, salt flats, ice sheets, tundra, and valleys. The altimeter tracker did not respond quickly enough over most non-ocean features; however, the waveform data have been retracked to achieve accuracy levels of better than a meter. The Seasat altimetric overland data base consists of more than 400 hours at a measurement rate of 0.1 second or potential overland/ice profiling lengths of approximately 10^7 km.

Overland analyses for south central Arizona, the Imperial Valley of California, the Yuma Valley of Arizona and the Florida Everglades have yielded surface elevations over smooth terrain accurate to plus or minus 1 m when correlated with large scale maps. Detailed analyses of ice topography in the polar regions have provided regional maps with a precision of a few decimeters.

Conclusions and Recommendations

Based on the presentations and discussions at the seminar, we make the following recommendations.

Sensors

Since measurements show that at 13.5 GHz, height errors due to EM bias are 10 to 25 cm for 5 m significant waveheights, this problem is worth eliminating from the data. Both experimental (aircraft and wavetank) investigations as well as theoretical studies are needed to understand and quantify this bias.

A modest incremental investment in a clever modification could produce a wealth of additional information with multibeam altimeters.

An additional rain gate would, besides providing rain information—which is useful in its own right—offer the prospect of identifying and correcting for a significant source of error: rain cells in the altimeter footprint.

Orbits and Data Processing

Seasat radial orbit accuracy has been improved to better than 50 cm. Further improvements are possible with existing data as more accurate earth gravity models and other geodetic models are developed.

Algorithms should be developed that continuously output to the geophysical data records (GDR) the statistical uncertainties in the derived parameters. This is done with maximum-likelihood and error-propagation methods. These uncertainties then allow the user to decide whether and how to employ the GDR's.

An updated Seasat GDR should be produced. This GDR would have a more accurate orbit, improved geophysical and instrument corrections, and estimates of uncertainties.

Future research should attempt to utilize the new, large-scale computing systems such as the Cyber 205 vector processor as well as the versatile minicomputer systems.

Scientific Applications and Models

Satellite altimetry offers a means, for the first time, to address various unknown aspects of the general (global, climatological mean) ocean circulation with a common observational system. Also of great importance, it will permit estimation of the evolution of the transient, synoptic scale circulation, which is required for understanding the ocean's response to various external and internal forcings. Some information on synoptic scale variability can be extracted from altimetric data at "face value." However, to extract much of the scientifically significant information, because of its nonuniform space-time sampling characteristics, the altimetric data will have to be passed through 4 dimensional data assimilation schemes, where dynamical and statistical methods are used to interpolate and extrapolate the data to a regular, space-time grid. The most complete and correct data interpretation may take place in the model-output rather than the model-input phase. Numerical ocean circulation models can already be useful for data interpretation in the sense of providing analogs for pattern recognition purposes. They should also be very useful for simulating altimetric data missions in order to assess the ability of such missions to recover, by inversion, an accurate characterization of the ocean's space-time circulation structure as a function of mission parameters. Overall, the future use of satellite remotely sensed data of the ocean, especially those associated with the ocean dynamical variables observed with the altimeter, will be critically linked to numerical ocean models, both statistical and dynamical.

Overland tracking by satellite altimeters represents an important new technique for terrain mapping, regional tectonic studies, monitoring of vertical crustal movements, and mapping ice sheet topography.

Scientific Communications and Cooperation

The further scientific use of satellite altimetry may be fostered by joint geodesy/ocean sciences sessions at AGU meetings. There will remain the need for in-depth discussions of scientific results in a workshop format; the Pilot Ocean Data System Science Steering Group may sponsor the next altimeteric workshop in 2 or 3 years.

European Missions

Since the Europeans will be active with their own altimetric satellites late in the decade, scientific communication between members of European and American scientific teams will be essential. Even more important is the promotion of freely-flowing, two-way data exchanges between these communities.

GEOSAT

Beginning in 1984, the Navy's GEOSAT promises to provide useful data for several years, bridging the GEOS-3/Seasat and the NROSS/TOPEX eras. since it will be the only altimetric satellite available in that period, it is important that the ocean science community have access to the data (at least to its unclassified ocean residual, i.e., after a classified geoid has been removed from the original data). Since there is likely to be extensive interest in this data set, it should be made broadly available through the Pilot Ocean Data System. However, there is a need to have adequate documentation and quality assurance of the classified aspects of the data stream in order to preserve the scientific integrity and utility of the data base.

Operational Applications

Synoptic sequences of altimetric topography on a weekly time scale could reveal the evolution of transient ocean circulation features, allowing the forecast, for example, of El Niño events which evolve over the course of a few months on an ocean basin-wide scale. Undoubtedly, operational use of wind, wind wave, and swell information can be anticipated.

Acknowledgments

J. Dana Thompson was responsible for organizing the modeling discussions, D. E. Barrick was responsible for the sensor discussions, J. G. Marsh chaired the measurement systems and orbit determination discussions, C. N. K. Mooers and R. E. Cheney chaired the oceanography applications discussions, and D. B. Lame served as seminar coordinator.

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then argued that a convective heat flux of this magnitude would freeze the magma chamber at fast spreading ridges; therefore the true value was likely much lower. He summarized seismic reflection data from the Lau Basin back-arc spreading center and the East Pacific Rise (EPR) at 9°N; the results indicate magma chamber depths of about 2 km in both cases. These depths, together with models of magma chamber shapes, suggest an axial heat flux of only about 0.2–0.5 x 10^{19} cal per year, with the lower value being favored.

Jenkins briefly reviewed evidence that ^3He is outgassed from the oceanic crust at a rate of about 6 x 10^{26} atoms per year. A part of this flux is reflected in the high ^3He concentrations near the East Pacific Rise at 20°S and 5°N, reflecting inputs from high temperature axial vents found along the crest of the EPR. The ^3He distribution, along with the dynamical models of *Stommel* [1982], suggest an axial ^3He flux from the EPR of about 0.6 x 10^{26} atoms per year. Assuming that the heat/^3He ratio in all axial vents is 7.5 x 10^{-8} cal per atom [*Jenkins et al.*, 1978], the heat flux for EPR axial vents is estimated by Jenkins as 0.5 x 10^{19} cal per year. A roughly equal axial flux might be expected from the remainder of the mid-ocean ridge system, giving a total high temperature axial heat flux of about 1 x 10^{19} cal per year. The remainder of the ^3He is presumably degassed in convection systems on the ridge flanks.

Kathy Crane (Lamont-Doherty Geological Observatory) reported that she had towed thermistors over a 400-km segment of the Juan de Fuca Ridge, and a 300-km segment of the East Pacific Rise. Temperature anomalies suggested the presence of roughly one vent field for each 100-km of ridge length. Crane has used a dynamical model to calculate axial convective heat fluxes from the temperature data. A globally extrapolated value of 1.5 x 10^{19} cal per year is obtained, which is close to the upper limit calculated by *Sleep et al.*, [1984] assuming complete crustal quenching.

John Edmond (MIT) discussed hot spring chemistry in the three hydrothermal systems studied by his group, those at the Galapagos Spreading Center [*Edmond et al.*, 1979], the East Pacific Rise at 21°N, and the sediment-covered ridge in the Guaymas Basin. In all systems, the discharging waters are depleted in Mg++ and $SO_4^{=}$, and highly enriched in Li+, K+, and Rb+. Na+ and Cl- concentrations range between approximately 90–110% of the seawater concentrations. H_2S concentrations are 4–9 mM. Values for *p*H and alkalinity are low or even negative for Galapagos and EPR, but (along with NH_3) high in Guaymas owing to reactions with the sediment prior to discharge.

Assuming, for the sake of discussion, that the axial convective heat flux is equal to Sleep's upper estimate of 0.5 x 10^{19} cal per year, one calculates that the axial removal rate of Mg++ is about 20% of the river input, that the axial input rates of alkalies are comparable to half of the river input, and that fluxes for Na and Cl are possibly large but of unknown sign. For an axial heat flux of 5 x 10^{19} cal per year favored by Edmond (calculated assuming all ^3He is lost in ridge axis vents with the aforementioned ^3He/heat ratio), the Mg++ and alkali fluxes dominate river inputs, whereas for the axial heat fluxes of 0.2 x 10^{19} cal per year estimated by Sleep, axial fluxes of these constituents are typically about 10% of the river value.

Two approaches were discussed at the symposium for estimating fluxes associated with ridge flank hydrothermal systems. Stanley Hart (MIT) outlined chemical changes in the top of the oceanic crust indicated by geochemical studies on basalts from Atlantic DSDP holes 417A and 418. Hart showed that K, Rb, and Cs concentrations of recovered basalts are far higher than concentrations in fresh basalt glasses, indicating uptake from solutions convecting through the crust on ridge flanks at low temperatures. The increases are so great, and these alkalis are strongly depleted in fresh mid-ocean ridge basalt, that the net fluxes of these elements integrated over all seawater-basalt alteration processes must be into the crust, regardless of the magnitude of the axial fluxes at which these alkalis are released into seawater. Hart estimated gross fluxes of K, Rb, and Cs into the crust during low temperature weathering as 15%, 75%, and 95% of the river fluxes, respectively.

Michael Bender (University of Rhode Island) discussed the composition of discharging geothermal solutions of three ridge flank hydrothermal systems: the Galapagos Mounds Hydrothermal Field (crustal age = 0.7 m.y.), a Mariana Trough hydrothermal system (3 m.y.), and a system on the western flank of the East Pacific Rise at 20°S (5 m.y.). Hydrothermal solutions at the two older sites had alkali and alkaline earth concentrations indistinguishable from bottom water values, suggesting that these solutions had passed through the crust without any substantial chemical reaction, perhaps because of low temperatures. The implication is that convection through crust older than 3 m.y. results in heat fluxes but not chemical fluxes. Hart summarized his geochronological studies sites 417A and 418, which also suggested that basalt alteration is complete within 3 m.y. [*Hart and Staudigel*, 1978; *Richardson et al.*, 1980].

The hydrothermal solutions discharging at the Galapagos Mounds Field are enriched in Ca++ and depleted in Mg++ and F- as a result of reaction with basalt [*Maris and Bender*, 1982; *Bender*, 1983]. Assuming that these solutions effectively discharge at a temperature of 27°C [*Becker and Von Herzen*, 1983], and that their element/heat ratios are typical of all ridge flank convection systems of crustal ages less than 3 m.y., one can estimate global Ca release rates and Mg and F uptake rates of about 10% of the river fluxes. What is surprising about Galapagos Mounds solutions is that the alkali concentrations are unchanged from bottom water values. Water/rock reactions in this system obviously differ from those involved in crustal alteration at sites 417A and 418.

Roger Anderson (Lamont-Doherty) discussed heat flow studies of ridge flank hydrothermal systems, as well as thermal modeling of these systems. He showed that flow through sediments can generally be constrained by heat flow measurements [*Fehn et al.*, 1983; R. N. Anderson and M. Hobart, unpublished manuscript]. Studies of conductive heat flow, pore pressure, and flow in DSDP holes all suggest that downwelling takes place over most of the seafloor in areas of convection, with upwelling being restricted to narrow zones.

This result is reproduced by heat flow modeling of ridge flank convection systems currently being done by David Gartling (Sandia Labs, Albuquerque) and Anderson. These models trace flow in the crust as a function of permeability, topography, and basal heat flow as the lithosphere cools and ages. The models predict maximum water-rock reaction temperatures of 150°C to 30°C, and residence times of water in the crust which increase from 0.1 to as long as 0.5 m.y., as the crust ages from about 3 m.y. to 100 m.y. If these values are correct, the lack of extensive chemical reactions in water circulating through old crust is surprising.

Don Elthon (University of Houston) summarized the stratigraphy of ophiolites and the way in which their chemistry and mineralogy are affected by alteration. In general, the igneous features of ophiolites include an extrusive basaltic carapace (0 to 1.5 km depth), a sheeted dike complex (1.5 to 2.0 km depth), and the underlying layer of cumulate gabbros and ultramafics. The overprint of hydrothermal metamorphism occurs at temperatures ranging from 100°C to 600°C. The extrusive basalts have been metamorphosed in the zeolite and greenschist facies; this process involves a high water/rock ratio (15–90, *Elthon et al.*, [1983]) and is accompanied by a large increase in the alkali concentrations [*Stern and Elthon*, 1979]. The sheeted dikes unit has been metamorphosed in the actinolite and greenschist facies, but metamorphism at this level in ophiolites is generally characterised by low water/rock ratios and only minor metasomatic changes in rock chemistry. Superimposed on this picture are complex retrograde metamorphic features, which occur as the crust cools during the aging process. While ophiolites clearly record extensive exchange with seawater, Elthon expressed the view that the metamorphic overprint on ophiolite geochemistry is not well enough understood at the present to constrain hydrothermal fluxes quantitatively.

The diversity of topics discussed in the symposium illustrates the wide range of information needed to understand and constrain hydrothermal fluxes. The component studies have generally been very successful in extending our understanding of the systems which have been studied. The great current challenge is to develop a methodology for using the results of detailed regional studies to constrain global heat, water, and chemical fluxes associated with deep sea hydrothermal processes.

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2, 327–328, 1974.

This meeting report was contributed by Michael L. Bender, *who is with the Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02881.*

Books (cont. from p. 85)

duces infiltration and causes runoff to be greater than that of an uncleared slope. This runoff enhancement caused by a decrease in permeability, known as "water harvesting" or "milking the hillside," obviously was understood by those who managed land and water in the ancient Negev. They could harvest perhaps not more than about 25% of the seasonal rainfall. Modern technology can increase this percentage by sealing, waterproofing, and stabilizing the soil cover. This source can be significant if one considers that 100 mm of rain on just 1 km² can produce 100,000 m³ (nearly 30 million gallons) of high-quality water.

This book is highly recommended to those readers who are interested in, or concerned with, deserts, people, or water. Fascination with the desert often borders on mysticism for those who know and love it. Perhaps our spiritual origins are in the desert in the same sense that our physical origins are in the sea. Time spent in the desert may represent a return to spiritual beginnings, rejuvenating the soul in much the same manner that time spent at the sea, the locus of our physical origins, rejuvenates the mind and body. One basic philosophy of the author is expressed in these few words on the last page: "Let us respect and love the desert, and seek to live with it, not rape or despoil it."

William Back is with the U.S. Geological Survey, Reston, VA 22092.

Classified

Announcement

New rates for classified advertising effective January 1, 1984:

RATES PER LINE

POSITIONS AVAILABLE

University of New Mexico/Paleomagnetism. The Department of Geology of The University of New Mexico invites applications for a tenure track full-time position as an Assistant Professor with a specialty in paleomagnetism beginning Fall 1984. The successful candidate will be expected to maintain an active research program and teach at the undergraduate and graduate level. The Department has sixteen full-time faculty, is located in a spectacular natural setting and has excellent analytical facilities.

Applicants should submit a resume, transcripts, and three letters of recommendation to R. Ewing, Department of Geology, Albuquerque, New Mexico 87131. The deadline for applications is April 10, 1984.

The University of New Mexico is an equal opportunity/affirmative action institution.

Faculty Position at Scripps Institution of Oceanography/Institute of Geophysics and Planetary Physics. Applications are invited for a tenure track faculty positon in the broad field of fluid dynamics which includes, for example, oceanography, both theoretical and observational, numerical modeling of fluids, and the dynamics of the earth's core. This appointment, as is the case for all other faculty positons at IGPP, will be made jointly with the teaching department of Scripps or another department at the University of California, San Diego. Qualifications include a Ph.D. in one of the sciences (including engineering), demonstrated competence in original research (presumably through publication in refereed journals), and in teaching at both the undergraduate and graduate level, which includes an appropriate command of both spoken and written English. Qualified applicants at all levels will be considered. Salary will be commensurate with the individual's qualifications. Please send applications and nominations to:

Professor Freeman Gilbert
University of California, San Diego
Institute of Geophysics & Planetary Physics
A-025
La Jolla, CA 92093.

Responses must be received by April 20, 1984.

The University of California is an affirmative action/equal opportunity employer.

Physicist. The National Oceanic and Atmospheric Administration (NOAA) announces a Physicist, GS-13, vacancy in the Environmental Research Laboratories, Space Environment Laboratory, Supporting Research Division, Boulder, Colorado. Starting salary at GS-13 level is $36,152. Duties include conducting research on the physics of the solar corona as related to the emission of matter and radiation ...

Planetary Geologist/Geophysicist: Jet Propulsion Laboratory, Earth & Space Sciences Division. The Planetary and Oceanography Section anticipates the availability of one or two fulltime, staff scientist research positions in the areas of planetary geology and geophysics. The rank of appointment is open, but applicants should be beyond the postdoctoral level with a demonstrated record of expertise and accomplishments in independent research and publication. We welcome applicants with interest in structural geology and geophysics as applied to the study of solid-body planets and natural satellites with emphasis on determining surface properties and processes on planetary objects using ground-base and spacecraft remote sensing data and applicable theoretical and experimental techniques. Applicants should send letter outlining their experience, professional goals, resume, and copies of pertinent publications to: Dr. William R. Ward, Manager, Planetology and Oceanography Section, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Dept. 134, Mail Stop 249-104, Pasadena, CA 91109.

An equal opportunity employer m/f.

Postdoctoral Position/Dalhousie University. A two-year position in the Oceanography Department is available for a person interested in marine geophysics. Specific work involves participation in heat flow studies across the margins of eastern Canada but broader opportunities also exist for self-motivated projects within the University or at Bedford Institute of Oceanography. A Ph.D. in geophysics and desire to work 1-2 mos/yr at sea are required. Experience with heat flow helpful but not essential. Send C.V. and names of two references to: Dr. K. E. Louden, Dept. of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4J1.

Clay Mineralogy/University of Illinois at Urbana-Champaign. The Department of Geology invites applicants for a tenure-track faculty position in clay mineralogy. We are seeking candidates who have clearly demonstrated the potential to be outstanding researchers in the general areas of mineralogy, crystallography and chemistry of clay minerals, in the origin, diagenesis, and metamorphism of argillaceous sediments and whose future research will complement our existing programs in the petrology and diagenesis of sediments, experimental studies of compaction and of kinetics of burial diagenesis, behavior of clay minerals during deformation, petroleum geology, and stable isotope geochemistry. In addition to the development of a strong research program, the successful candidate is expected to participate in all aspects of teaching and advising at the graduate and undergraduate levels.

The Department of Geology houses a variety of ...

... April 1, 1984 to Dr. Albert V. Carozzi, Chairman, Search Committee, Department of Geology, 245 Natural History Building, 1301 W. Green Street, Urbana, IL 61801. Phone: 217/333-3008.

The University of Illinois is an equal-opportunity/affirmative action employer.

... Salary is negotiable. Deadline for applications—April 1, 1984. Contact Dr. Bjorn Lamborn, Chairman, Department of Physics, Florida Atlantic University, Boca Raton, FL 33431, Tel (305) 393-3381.

Florida Atlantic University is an affirmative action/equal opportunity employer.

Geophysicist/University of Minnesota. The Department of Geology & Geophysics invites applications for a tenure track position in solid-earth geophysics beginning fall 1984. We seek a Ph.D. and preferably some postdoctoral experience. ...

Faculty Position/UCLA. The Department of Earth and Space Sciences, UCLA, seeks applications for a regular faculty position in the area of sedimentology, sedimentary petrology, basin analysis, stratigraphy, and regional geology. A Ph.D. or ...

... Head, Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721.

The University is an equal opportunity/affirmative action employer.

POSITIONS WANTED

Seismologist. Ph.D. early 1981 seeking research or teaching position. Experience includes reflection seismology on megasets, refraction modeling, crustal studies of continental deformation, microearthquake surveys, intimate knowledge of computers including VAX-11/780 VMS and CP/M of microcomputer. Box 020, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

STUDENT OPPORTUNITIES

Opportunity for Graduate Study in Igneous Petrology/Isotope Geochemistry—Southern Methodist University. The Department of Geological Sciences at Southern Methodist University in Dallas, Texas seeks outstanding individuals interested in a PhD program in igneous petrology and/or isotope geochemistry. The successful applicant should have a strong background in geology, chemistry, and mathematics and an interest in volcanic processes. Research will involve participation in a field-oriented petrological, geochemical, and isotopic study of Late Cenozoic volcanism in the Chilean Andes. For further details and applications please contact either:

Dr. R. S. Harmon (214) 692-3075
or
Dr. M. A. Dungan (214) 692-2752
Department of Geological Sciences
Southern Methodist University
Dallas, Texas 75275.

Research Assistantships/University of Maryland. The Meteorology Department of the University of Maryland has research assistantships available for graduate students, Fall Semester 1984. The Department offers courses of study leading to the degrees of Master of Science and Doctor of Philosophy in meteorology. Students with a bachelor's degree in meteorology, the physical sciences, mathematics, or engineering are invited to apply.

Situated in the Maryland suburbs of Washington, D.C., the University is in an ideal location for interaction with the large meteorological community of the area. The Department has cooperative research agreements with the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration. Access to facilities of these and other government agencies, including the large computers at the National Center for Atmospheric Research and NASA, are important resources for students of Maryland. The Cooperative Institute for Climate Research and the Center for Ocean-Land-Atmosphere Interactions, both established recently on campus, offer the student expanded opportunities for advanced study and research in climate analysis, modeling and prediction. A large number of private and government agencies within the metropolitan Washington, D.C. area offer employment opportunities.

Interested individuals are encouraged to write for more information to the following address: Chairman, Department of Meteorology, University of Maryland, College Park, MD 20742.

Research Fellowships at the University of Notre Dame. Fellowships in groundwater physics, groundwater chemistry, anaerobic processes and bioengineering are currently available in the Environmental Engineering Program of the Civil Engineering Department. Successful applicants will be awarded annual stipends of up to $1000/mo. plus full tuition. For additional information, contact Dr. Aaron A. Jennings, Department of Civil Engineering, University of Notre Dame, Notre Dame, IN 46556 (219-239-5846).

State University of New York at Buffalo/Assistantship Opportunities. The Department of Geological Sciences invites graduate applicants for Fall 1984. Graduate/Teaching assistantships offer a stipend up to $5500.00 for 10 months, plus tuition waiver. Special assistantships in geophysics, geochemistry-mineralogy, and glaciology carrying a 10-month stipend of $7200.00 plus tuition waiver are available. Additional summer support is possible. Applications can be obtained from the Department of Geological Sciences, 4240 Ridge Lea, Amherst, NY 14226, 716-831-3051. Deadline for receipt of all materials is March 30, 1984.

The State University of New York at Buffalo is an affirmative action/equal opportunity employer and invites applications from minority and women candidates. No person in whatever relation with SUNYAB shall be subject to discrimination on the basis of age, color, national origin, race, religion, or sex.

AGU

Science and Policy on Capitol Hill

Arthur B. Weissman

I spent my year as the 1982–1983 AGU Congressional Science Fellow as legislative assistant to Sen. Christopher J. Dodd (D-Conn.), covering environment and energy issues. I offer this final report of my year not only for potential Congressional Science Fellows but for all readers of *Eos* who may want to contribute to science policy making (but are afraid to try).

My primary goal was to get a broad exposure to issues, organizations, people, and the legislative process; this I achieved beyond my expectation. Congress, remarkably, is set up like a vast marketplace: There are vendors (the lobbyists and interest groups) and consumers (the constituents), and each group makes its desires known to the members of Congress, who act as brokers. Issues are strewn about like so many fish—some stale and rancid; others fresh and meaty, the catch of the day. And there is no real respite: Problems requiring a response (if not a solution) will seek out even the most diffident Member or staffer.

What makes Congress frustrating is that the market operates on such a strange, hurry-and-wait schedule. Of course, Congress can act quickly when absolutely necessary, as in its adoption of the Social Security Act last year. But where consensus has not developed, or where an issue is too complex or abstract to merit immediate consideration, Congress can be notoriously slow in acting. In my field, environmental science, there were a number of pending issues which were either too complex or too controversial to receive the action they warranted—reauthorization of the Clean Air Act and the Clean Water Act and consideration of an acid deposition control program, to name only a few. I watched in frustration as budgetary and defense matters marched through, and many of the issues on which I (and many others) worked hard and long remained stalled either in committee or on the floor. The lesson, though hard, was very clear.

Nonetheless, I gained considerable experience working on legislation and seeing what the legislative process entails. I developed some proposals for acid deposition control and some amendments on the ocean discharge waiver issue (Sec. 301(h) of the Clean Water Act), which directly affected Connecticut. In the course of drafting these bills for the Senator I learned how powerful can be many interest groups (helpful or troublesome, depending on their stand) and how possessively Congressional committees guard their jurisdictions when noncommittee members offer proposals. I learned too how the scientific aspects of the issues, which occupied much of my time, played in counterpoint (or often in mere accompaniment) to other political considerations. And I saw how both science and politics got transmogrified by counsel into cold, statutory language that elucidated neither the science nor the politics behind the measure.

There is much else, of course, that occupies a Senator's office besides legislation, and I did a good share of casework involving constituent problems with federal laws and agencies. Though eschewed by many, such casework reveals much about how government actually works (or doesn't work). It was gratifying to be able to help out towns, companies, and individuals through the weight of the Senator's office. While it can be frustrating to be besieged by endless requests and demands, I realized that citizens are better off for having members of Congress who are directly accountable to them.

There is good news for the scientist who would influence legislation. With the plethora of issues to consider, much of the substance of issues and of the remedies proposed goes unexamined in Congress. Scientists can provide useful, substantive advice even if they do not work on the Hill, especially for the personal offices of Senators and Congressmen, which rarely have staff scientists at hand to help them with complex technical issues. Concerned scientists should develop a relationship with the staff of their own Senator or Congressman, particularly with the legislative director and the legislative assistant in the relevant area. Correspondence is not sufficient (the Hill operates on personal contacts), so telephone calls and personal visits are always advised. An alternate route for influencing Congressional affairs is to become an advisor to an interest group. In either case, a persuasive argument communicated in a personal, direct way can be a significant influence on a Member of Congress (or his staff) looking for clarity in a maze of ideas, people, and paper.

Scientists (and science) can in fact do a lot to shape events in Congress. A good example of bad influence by scientists is the money Congress awarded last year to Catholic University and Columbia for materials science laboratories without any peer review or Congressional committee authorization. For those who think that science is irrelevant in policy making, there is the recent counterexample of budget director David Stockman holding up an acid deposition control program because of scientific uncertainty. Admittedly, the Administration's bottom line here is money and votes, not ecosystems, but scientific considerations play a big role in the management of this problem.

There is much, however, that a scientist (and science) cannot do in Congress. Scientific information and reasoning in themselves do not provide usable answers to Congressional decision makers. Science must be transformed and cast in terms of social value judgments, which are the real fare of Congress. The acid deposition issue ultimately requires a balancing of regional and social costs and values: Environmental protection in one place may necessitate increased living costs or even job losses in another. What legislators need from scientists is a clarification of effects and consequences. For example, in the ocean discharge issue, scientists should clarify the possible effects on water quality of increased biological oxygen demand and toxic loadings owing to reduced municipal sewage treatment.

Decisions on policy are value judgments based on many different considerations—social, economic, and political as well as scientific. The scientist may consider herself or himself equipped to render such judgments (staff scientists are in fact asked to make such recommendations), but the scientist should realize that, in doing so, a professional boundary is being crossed. Charting the course of that fine line, and watching it bend and bulge with the flow of events, are among the inimitable challenges and adventures of working as a scientist in Congress.

Arthur B. Weissman is with the Environmental Protection Agency in Washington, D. C.

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Donald K. Balmer (H), Mark Bushnell (O), Charles J. Garcia (SS), Enzo Mantovani (S), Vicky Pease (T), James E. Quick (V), Gerard Schuster (S), Endre Skaar, Michael Underwood (T), John J. Whipple (H).

Student Status

Thedore G. Apotria (T), D. Kent Backhus (T), William R. Blackport (H), William J. Dunn (GP), Steven Eckes (SS), Horacio Ferriz (V), Brian Hausback (V), Robert W. Lane (H), Desmond Lee Ling Chye (S).

Stewart L. Moses (SM), Douglas Munsell (G), Gee-Shang Pan (S), Daniel E. Sampson (V), Ingrid Sandahl (SM), Terry Sewards (GP), James E. Stefano (T), Timothy Sutko (H), Sally Jo Sutton (T).

Gerard Tango (S), Joseph F. Titzer (S), Frank Toffoletto (SM), David M. Traill (S), Gail T. Vogt (T), Jonathan L. Wilson (S), Mark Zielinski (T).

Meetings

Announcements

Applied Numerical Modeling

December 28–31, 1984 Fourth International Conference on Applied Numerical Modeling, Tainan, Taiwan. (S. Y. Wang, School of Engineering, Univ. of Mississippi, University, MS 38677; telephone: 601-232-7219.)

Abstracts of approximately 300 words should be sent to the above address no later than April 1. There will be general sessions, technical sessions, and panel discussions, as well as a tour of research and teaching facilities at the host institution. Featured lectures and invited and contributed papers will focus on computational mechanics. The topics include solid mechanics, soil mechanics and geomechanics, structural analysis and design, fluid flow simulation, hydraulic and hydrologic models, biosystem analysis and simulation, numerical modeling methodology, and dynamic systems.

Freshwater Chemistry

September 10–14, 1984 International Symposium on Hydrochemical Balances of Freshwater Systems, Uppsala, Sweden. Sponsors, Swedish Natural Science Research Council, UNESCO, and the International Association of Hydrological Sciences. (M. Falkenmark, Exec. Sec. NFR, Comm. for Hydrology, Box 6711, S-11385 Stockholm, Sweden.)

The deadline for early registration for the symposium is April 1. Symposium and workshop sessions will take up such topics as water interaction with soil and rock, water quality problems in developing countries, data collection, human influence on freshwater systems, sorption-desorption phenomena in natural systems, hydrochemical and sediment-geochemical data as a tool for deciphering hydrological processes, and hydrochemical budgeting and modeling for catchment areas, lakes, and other hydrological units.

In conjunction with the symposium, an excursion to the Verka River Basin, one of Sweden's Representative and Experimental Basins within the International Hydrological Decade, will take place on Wednesday, September 12.

Lake Management

October 16–19, 1984 International Symposium on Lake and Watershed Management: Local Involvement, McAfee, N. J. Sponsor, North American Lake Management Society. (Harry Gibbons, Jr., Dept. of Civil and Environmental Engineering, Washington State Univ., Sloan Hall 141, Pullman, WA 99164–2912.)

Abstracts of not more than one double-spaced page must be submitted by April 15. The symposium will focus on material relating to lake and watershed management techniques and research oriented toward management goals, including grass roots participation. For the first time, an award will be presented for the best contributed student paper; Hydrolab has established this award.

The following topic codes should be used to identify papers: A1, water quality assessment methods; A2, restoration techniques; A3, quality criteria and standards; A4, economic benefits of improving water quality; B1, point source pollution control techniques; B2, waste load allocation techniques; B3, nonpoint source pollution control techniques; B4, water shed management; B5, land use options for management purposes; C1, modeling techniques and innovations; C2, toxics in surface waters; C3, macrophyte control; C4, taste and odor control and dynamics; C5, biomanipulation techniques; C6, fishery management.

D1, acidic precipitation effects on surface waters; D2, agricultural runoff and water quality; D3, urban runoff and water quality; D4, mining effects on water quality; E1, political realities of lake management; E2, the role of lake associations and watershed districts; E3, public awareness and education concepts; E4, distribution and financial options for water quality management; E5, case studies of successful water quality improvements; E6, case studies of trends of eutrophication in surface waters; and E7, reservoirs and lakes comparisons.

Air and Oceans in Northern Latitudes

October 3–5, 1984 Symposium on Meteorology and Oceanography of Northern High Latitudes, Anchorage, Alaska. Sponsors, American Meteorological Society and AAAS. (Stuart Bigler, National Weather Service, 701 C St., P.O. Box 23, Anchorage, AK 99513.)

Abstracts of fewer than 200 words should be submitted by April 1.

Papers are solicited on all aspects of high latitude meteorology and oceanography, although the focus will be on time scales ranging from less than a day to several months. Sessions are planned on the following topics: air-sea-ice interaction in the high latitudes of the North Pacific; long-range forecasting for the Alaskan region; meteorological aspects of air pollution in the far north, with special emphasis on the Fairbanks region; and the variability and predictability of sea ice conditions in Alaskan waters. Papers describing results from the Bering Sea Marginal Ice Zone Experiment (MIZEX) are encouraged.

Authors will be notified of acceptance of papers in early May.

Water Management

April 4–6, 1984 Conference on Management Techniques for Water and Related Resources, Carbondale, Ill. Sponsor, American Water Resources Association, Illinois Section. (DeLaine Lynch, Geography Dept., Southern Illinois Univ. at Carbondale, Carbondale, IL 62901; tel.: 618-536-3375.)

Topics to be covered include urban water supply management (demand forecasting techniques, demand management and conservation, drought planning and management, and financing and rate-making); water quality (oil brine, groundwater pollution and hazardous wastes, and drinking water quality); floodplain management; irrigation for agriculture; and water-based recreation.

Goddard Symposium

The theme of the 22nd Goddard Memorial Symposium, to be held March 15–16, 1984, at the NASA Goddard Space Flight Center in Greenbelt, Md., will be "Permanent Presence—Making it Work." The meeting will address the varied aspects of design, establishment, and operation of permanent manned and unmanned facilities in near-earth space. Sessions will focus on missions, architecture, productivity, and technology, including international cooperation, long range goals, commercial prospects, operations and logistics, and space station configurations.

The meeting is sponsored by the American Astronautical Society, 6060 Duke St., Alexandria, VA 22304 (tel.: 703-751-7721 or 751-7323). Ivan Bekey of the National Aeronautics and Space Administration is the symposium general chairman. For those who cannot attend the meeting, information about the proceedings should be obtained from Horace Jacobs, Univelt, Inc., P.O. Box 28130, San Diego, CA 92128 (tel.: 619-746-4005).

Geophysical Year

A date at the end of an entry indicates the issue of Eos in which a full meeting announcement was run.

A list of abbreviations used in the Geophysical Year calendar appears at the end of the calendar.

Future AGU Meetings

Fall Meetings

Dec. 3–7, 1984, San Francisco *(Abstracts due mid-September 1984)*

Dec. 9–13, 1985, San Francisco *(Abstracts due mid-September 1985)*

Spring Meetings

May 14–18, 1984, Cincinnati

May 27–31, 1985, Baltimore *(Abstracts due early March 1985)*

Chapman Conferences

The Magnetospheric Polar Cap August 6–9, 1984, Fairbanks *(Abstracts due May 1, 1984)*

1984

March 11–16 American Society of Photogrammetry and the American Congress on Surveying and Mapping National Meeting, Washington, D.C. (Thomas J. Lanterborn, Rte. 1, Box 127, Waterford, VA 22190; tel.: 703-882-3334.)

March 12–16 15th Annual Lunar and Planetary Science Conference, NASA Johnson Space Center, Houston, Tex. Sponsors, AGU, Lunar and Planetary Institute, Meteoritical Society, and American Astronomical Society. (15th Lunar and Planetary Science Conference Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058; tel.: 713-486-2150.) (Nov. 22, 1983.)

March 13–15 Fourth Biennial SEG/U.S. Navy Joint Technical Symposium on Three-Dimensional Marine Data Collection, Processing, Interpretation, and Presentation, National Space Technology Laboratories (NSTL), Bay St. Louis, Miss. (J. A. Ballard, Chairman, NORDA, NSTL, MS 39529; tel.: 601-688-4760.) (Nov. 1, 1983.)

March 14–17 1984 GSA Northeastern Section Meeting, Providence, R. I. (Jeff Sgambat, Geraghty and Miller, Inc., 844 West St., Annapolis, MD 21401; tel.: 301-268-7760.) (Aug. 9, 1983.)

March 19–23 Fifth Northern Research Basins Symposium and Workshop, Vierumäki, Finland. (Charles Slaughter, Chairman, U.S. Working Group, Institute of Northern Forestry, USDA Forest Service, 308 Tanana Dr., Fairbanks, AK 99701, or Olli Fassanen, Secretary, Organizing Committee, Hydrological Office, Box 436, 00101 Helsinki 10, Finland.)

March 19–24 Third International Symposium on Land Subsidence, Venice, Italy. Sponsor, IAHS. (A. I. Johnson, Program Chairman, Third International Symposium on Land Subsidence, Woodward-Clyde Consultants, 7600 East Orchard Rd., Englewood, CO 80111.)

March 22–29 Seventh International Symposium on Equatorial Aeronomy (ISEA), Hong Kong. Sponsors, ICSU Committee on Space Research, IUGG, IAGA, IAMAP, and URSI. (S. Matsushita, Chairman, ISEA, High Altitude Observatory, NCAR, P.O. Box 3000, Boulder, CO 80307; tel.: 303-494-5151.)

March 26–27 GSA South-Central Section Meeting, Dallas, Tex. (Jean Latulippe, Meetings Dept., GSA, Boulder, CO 80301; tel.: 303-447-2020.)

March 26–28 NOAA's Environmental Satellites Come of Age: Applications for Users and Opportunities for the Marketplace, Washington, D.C. Sponsor, National Environmental Satellite, Data and Information Service. (SES, Inc., P.O. Box 2697, Springfield, VA 22152; tel.: 800-424-2735, ext. 528.) (Jan. 24, 1984.)

March 26–29 Lectures on Geophysical and Solar Activity Indices, Han-Sur-Lesse, Belgium. Sponsor, Institut D'Aeronomie Spatiale de Belgique. (L. Bossy and J. Lemaire, Institut D'Aeronomie Spatiale de Belgique, 3, Avenue Circulaire, B 1180 Bruxelles, Belgium.)

March 26–29 International Conference on Groundwater Quality Research, Tulsa, Okla. (Sheri Dunn, Univ. Center for Water Research, Oklahoma State Univ., 203 Whitehurst, Stillwater, OK 74078; tel.: 405-624-6995.) (Feb. 14, 1984.)

March 28–30 International Symposium on Earthquake Relief in Less Industrialized Areas, Zurich, Switzerland. (Swiss National Committee for Earthquake Engineering, SIA Postfach, CH-8039, Zurich, Switzerland.)

April Arctic Water Pollution Research: Applications of Science and Technology, Yellowknife, N.W.T., Canada. (W.A. Bridges, Bridges Values, Ltd., P.O. Box 3181, Halifax South Post Office, Nova Scotia B3J 3H5, Canada.)

April CSCE/ASCE Cold Regions Engineering Specialty Conference on Northern Resource Development, Edmonton, Alberta, Canada. (Daniel W. Smith, Dept. of Civil Engineering, Univ. of Alberta, Edmonton, Alberta T6G 2G7, Canada.)

April International Conference on Recent Advances in Mineral Science and Technology, Johannesburg, South Africa. Sponsor, South African Council for Mineral Technology (Mintek). (The Conference Secretary (CSS), Mintek, Private Bag X3015, Randburg, 2125 South Africa.)

April 2–4 Second National Symposium and Exposition on Groundwater Instrumentation, Las Vegas, Nev. Sponsor, National Water Well Association. (D. M. Nielsen, Conference Director, NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.) (Nov. 1, 1983.)

April 3–5 Interdisciplinary Conference on Meeting the Water Needs of the Southwest, Dallas, Tex. (Michael A. Collins, School of Engineering and Applied Science, Southern Methodist Univ., Dallas, TX 75275; tel.: 214-692-3000.) (July 12, 1983.)

April 4–6 GSA Joint North-Central Section and Southeastern Section Meeting, Lexington, Ky. (Jean Latulippe, Meetings Dept., GSA, Boulder, CO 80301; tel.: 303-447-2020.)

April 4–6 Conference on Management Techniques for Water and Related Resources, Carbondale, Ill. Sponsor, American Water Resources Association, Illinois Section. (DeLaine Lynch, Geography Dept., Southern Illinois Univ. at Carbondale, Carbondale, IL 62901; tel.: 618-536-3375.) (March 6, 1984.)

April 8–11 13th Annual Rocky Mountain Groundwater Conference, Great Falls, Mont. (W. A. Van Voast, Montana Bureau of Mines and Geology, 3021 Sixth Ave. North, Billings, MT 59101; tel.: 406-259-9834.)

April 9–11 Sixth Annual Groundwater Heat Pump Conference, Columbus, Ohio. Sponsor, National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

April 11–13 International Conference on Hydraulic Design in Water Resources Engineering: Channels and Channel Control Structures, Southampton, UK. (K. V. H. Smith, Dept. of Civil Engineering, The University, Southampton SO9 5NH, UK.)

April 24–26 Fourth Annual Front Range Branch Hydrology Days, Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State Univ., Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.) (Nov. 22, 1983.)

April 24–27 Pacific Conference on Marine Technology (PACON 84), Honolulu, Hawaii. Sponsors, Marine Technology Society, AGU. (PACON 84, Center for Engineering Research, Univ. of Hawaii at Manoa, Honolulu, HI 96822; tel.: 808-948-7558 or 7449.) (Aug. 16, 1983.)

April 26–27 Sixth Annual Texas A&M Geodynamics Research Program Symposium on Collisional Tectonics: Deformation of Continental Lithosphere, College Station, Tex. Sponsors, Inter-Union Commission on the Lithosphere, NASA, and the Commission on Marine Geophysics of IAPSO. (Texas A&M Geodynamics Office, College Station, TX 77843–3114; tel.: 409-845-8477.)

April 29–May 4 Penrose Conference on Processes and Products of Multistage Melting and Metasomatism in the Mantle, Gold Canyon Ranch, Ariz. Sponsors, GSA and USGS. (J. E. Nielson, USGS, 345 Middlefield Rd., MS 75, Menlo Park, CA 94025.) (Oct. 25, 1983.)

April 30–May 3 International Association for Great Lakes Research Annual Conference, St. Catherines, Ontario, Canada. (J. Terasmae, Dept. Geological Science, Brock Univ., St. Catherines, Ontario L2S 3A1, Canada; tel.: 416-688-5550.)

April 30–May 3 30th Annual Technical Meeting: Environmental Integration Technology Today for a Quality Tomorrow, Orlando, Fla. Sponsor, Institute of Environmental Sciences. (Institute of Environmental Sciences, 940 E. Northwest Hwy., Mount Prospect, IL 60056; tel.: 312-255-1561.)

April 30–May 4 Penrose Conference on Structural Styles and Deformational Fabrics of Accretionary Complexes, Eureka/Arcata, Calif. Sponsor, GSA. (Western Experience, 2450 Central Ave., Suite F-2, Boulder, CO 80308; tel.: 303-449-3362.)

May–June 8th International Congress on Irrigation and Drainage, Fort Collins, Colo. (ICID, 48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India.)

May 7–9 Third Symposium on Arctic Air Chemistry, Downsview, Ontario, Canada. (L. A. Barrie, Atmospheric Environment Service, 4905 Dufferin St., Downsview, Ontario M3H 5T4, Canada; tel.: 416-667-4785; or K. A. Rahn, Graduate School of Oceanography, Univ. of Rhode Island, Narragansett, RI 02882–1197; tel.: 401-792-6234.) (Aug. 23, 1983.)

May 14–18 Geological Assoc. of Canada and Mineralogical Assoc. of Canada Joint Annual Meeting, London, Ontario, Canada. (N. D. MacRae, Dept. of Geology, Univ. of Western Ontario, London, Ontario N6A 5B7, Canada.)

May 14–18 AGU Spring Meeting, Cincinnati, Ohio. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

May 20–23 International Symposium on Deep Observation and Sampling of the Continental Crust Through Drilling, Tarrytown, N. Y. (Barry Raleigh, Director, Lamont-Doherty Geological Observatory, Palisades, NY 10964; tel.: 914-359-2900.)

May 21–23 International Groundwater Symposium on Groundwater Resources Utilization and Contaminant Hydrogeology, Montreal, Canada. Sponsors, Canadian National Chapter of the International Association of Hydrogeologists and the Canadian Water Well Association. (A. Kohut, Chairman, International Groundwater Symposium Montreal '84, Ministry of the Environment, 765 Broughton St., Victoria, B. C., V8V 1X5, Canada.)

May 21–23 Symposium on Climate History, Periodicity, and Predictability, N.Y. (John E. Sanders, Dept. of Geology, Barnard College, Columbia Univ., New York, NY 10027; tel.: 212-280-4312.) (Aug. 23, 1983.)

May 21–25 Ninth Conference on Weather Modification, Park City, Utah. Sponsor, American Meteorological Society. (Edward Hindman, Dept. Atmospheric Science, Colorado State Univ., Ft. Collins, CO 80523; tel.: 303-491-8311.)

May 23–25 Fourth National Symposium and Exposition on Aquifer Restoration and Groundwater Monitoring, Columbus, Ohio. Sponsor, National Water Well Association. (NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

May 23–25 Workshop on Precipitation Enhancement, Park City, Utah. Sponsors, National Science Foundation and American Meteorological Society. (Roscoe Braham, Dept. of Geophysical Sciences, Univ. of Chicago, Chicago, IL 60637; tel.: 312-962-8123.)

May 24–26 Symposium on the History of Soil and Water Conservation, Columbia, Mo. Sponsors, Missouri Cultural Heritage Center at the Univ. of Missouri, the Agricultural History Society, and the Soil Conservation Service of the U.S. Dept. of Agriculture. (Susan Flader, Dept. of History, Univ. of Missouri, Columbia, MO 65211; tel.: 314-882-2481 or 314-442-1058; or Douglas Helms, Historian, Soil Conservation Service, P.O. Box 2890, Washington, DC 20013; tel.: 202-382-0042.)

May 28–June 2 12th International Congress on Irrigation and Drainage, Fort Collins, Colo. Sponsors, U.S. Committee on Irrigation, Drainage, and Flood Control (USCIDFC), AGU. (USCIDFC, P.O. Box 15326, Denver, CO 80215.)

May 29–31 Urban Water '84—A Time For Renewal, Baltimore, Md. Sponsor, American Society of Civil Engineers Water Resources Planning and Management Division. (Harold Day, College of Environmental Science, Univ. of Wisconsin at Green Bay, Green Bay, WI 54301; tel.: 414-465-2251.)

May 29–June 1 Joint Meeting of the 11th Annual Meeting of the Canadian Geophysical Union and the 18th Annual Congress of the Canadian Meteorological and Oceanographic Society, Halifax, Nova Scotia, Canada. (S. D. Smith or H. R. Jackson, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2.) (Aug. 30, 1983.)

June 4–7 Symposium on Climate and Paleoclimate of Lakes, Rivers, and Glaciers, Igls, Austria. Sponsor, International Commission on Climate, IAMAP. (M. Kuhn, Institut fuer Meteorologie ...)

Meetings (cont. on p. 92)

Meetings *(cont. from p. 91)*

gle und Geophysik, Schöpfstrasse 41, A-6020 Innsbruck, Austria.) (Oct. 25, 1983.)

June 4–8 IWRA Seminar on River Basin Strategy, Linköping, Sweden. (U. Lohm, Water Theme, Linköping Univ., S-58183, Linköping, Sweden.) (Oct. 18, 1983.)

June 4–8 Seventh International Conference on Atmospheric Electricity, Albany, N. Y. Sponsors, IAMAP International Commission on Atmospheric Electricity, AMS, and AGU. (R. E. Orville, Atmospheric Electricity Conference, E.S. 214, 1400 Washington Ave., SUNY, Albany, NY 12222; tel.: 518-457-3987.) (July 20, 1983.)

June 4–8 Third International Conference on Urban Storm Drainage, Göteborg, Sweden. Sponsors, IAHR and International Association on Water Pollution Research. (P. Malmqvist, c/o Dept. of Hydraulics, Chalmers Univ. of Technology, S-412 96 Göteborg, Sweden.)

June 6–9 Second American Conference on Ice Nucleating Bacteria, Flagstaff, Ariz. (Ralph M. Billy Research Center, Box 6015, Northern Arizona Univ., Flagstaff, AZ 86011.) (Nov. 15, 1983.)

June 10–15 65th Annual Meeting of the American Association for the Advancement of Science (Pacific Division), San Francisco, Calif. (John H. Vann, Dept. of Geography, California State Univ., Hayward, CA 94542; tel.: 415-881-3193.) (Jan. 31, 1984.)

June 11–12 Fifth European Conference on Environmental Pollution, Amsterdam, The Netherlands. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

June 11–13 Symposium on Critical Assessment of Forecasting in Western Water Resource Management, Seattle, Wash. Sponsors, AWRA and AGU. (G. R. Minton, President, Resource Planning Assoc., 113 Lyno St., Seattle, WA 98109; tel.: 206-282-1181.) (June 28, 1983.)

June 18–22 Fifth International Conference on Finite Elements in Water Resources, Burlington, Vt. Sponsors, Univ. of Vermont, AGU. (J. P. Laible, Dept. of Civil Engineering and Mechanical Engineering, Univ. of Vermont, Burlington, VT 05405; tel.: 802-656-3800.)

June 19–21 Third International Conference on Marine Simulation, Rotterdam, The Netherlands. Sponsor, Maritime Research Institute Netherlands. (Secretariat MARSIM 84, c/o Maritime Research Institute Netherlands, P.O. Box 1555, 3000 BN Rotterdam, The Netherlands.)

June 23–30 Penrose Conference on Melanges of the Appalachian Orogen, Newfoundland, Canada. Sponsor, GSA. (Brenda E. Lorenz, Dept. of Earth Sciences, Memorial Univ. of Newfoundland, St. Johns, Newfoundland A1B 3X5 Canada.) (June 28, 1983.)

June 24 International Conference on Geomembranes, Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24 International Symposium on Impermeable Barriers for Soil and Rock, Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24–30 14th International Conference on Mathematical Geophysics, Loen, Norway. (L. Tronrud, NTNF/NORSAR, P.O. Box 51, N-2007 Kjeller, Norway; telex: 18147 kein.)

June 25–27 Rock Mechanics in Protection and Productivity, 25th U.S. Symposium on Rock Mechanics, Evanston, Ill. Sponsor, AGU. (Charles H. Dowding, Dept. of Civil Engineering, Northwestern Univ., Evanston, IL 60201; tel.: 312-492-7270.) (Sept. 13, 1983.)

June 25–July 7 ICSU Committee on Space Research 25th Meeting, Graz, Austria. (Richard C. Hart, Space Science Board, JH-828, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

June 25–July 7 Symposium on Space Observations for Climate Studies, Graz, Austria. Sponsors, World Climate Program IS, Ruisenberg, Secretary, COSPAR Committee A, NCAR, Boulder, CO 80307.) (July 19, 1983.)

June 20–28 Symposium of the Achievements of the International Magnetospheric Study, Graz, Austria. Sponsor, ICSU Scientific Committee on Solar-Terrestrial Physics. (J. G. Roederer, Geophysical Institute, Univ. of Alaska, Fairbanks, AK 99701.)

June 26–28 1984 International Conference on Lightning and Static Electricity, Orlando, Fla. Sponsors, NOAA, IEEE, SAE-AE4 Committee, and several military and civilian air transportation agencies in the U.S. and UK. (J. J. Fisher, Conference Chairman, U.S. Naval Air Systems Command, P.O. Box 15050, Arlington, VA 22215; tel.: 202-692-7822; or C. Odam, European Coordinator, Royal Aircraft Establishment, Farnborough, Hants, GU14 6TD UK; tel.: 0252-24461, ext. 2658.) (Sep. 8, 1983.)

June 26–28 International Symposium on Deep Structure of the Continental Crust: Results from Reflection Seismology, Ithaca, N.Y. Sponsor, ACU. (Muawia Barazangi, Conference Coordinator, Dept. of Geological Sciences, Cornell Univ., Ithaca, NY 14853; tel.: 607-256-6411 or telex: 937478.)

July 2–5 Symposium on the Physics of the Magnetosphere-Ionosphere Connection, Graz, Austria. Sponsor, Committee on Space Research ICSU. (R. E. Schmerling, EE-8, NASA Headquarters, Washington, DC 20546.) (Dec. 6, 1983.)

July 5–6 Second Symposium on Plasma Double Layers and Related Topics, Innsbruck, Austria. (R. Schrittwieser, Inst. for Theoretical Physics, Univ. of Innsbruck, Sillgasse 8, A-6020 Innsbruck, Austria.)

July 9–13 International Symposium on Space Techniques for Geodynamics, Sopron, Hungary. Sponsors, Hungarian Academy of Sciences and IAG/COSPAR Joint Commission on the International Coordination of Space Techniques for Geodesy and Geodynamics. (Ch. Reigber, Deutsches Geodätisches Forschungsinstitut, Abt. I, Marstallplatz 8, D-8000 Munich 22, FRG.)

July 9–13 Longitude Zero, Greenwich, UK. Sponsors, International Union for the History and Philosophy of Science and the International Astronomical Union. (Conference Officer, "Longitude Zero" Symposium, National Maritime Museum, Greenwich, London SE10 9NF, UK.) (Nov. 15, 1983.)

July 10–14 The Case for Mars II, Boulder, Colo. Sponsor, Mars Institute of the Planetary Society. (Helen Hart, Laboratory for Atmospheric and Space Physics, Univ. of Colorado, Boulder, CO 80309; tel.: 303-492-8822; Carol Stoker or Tom Meyer, Case for Mars, P.O. Box 4877, Boulder, CO 80306; tel.: 303-494-8144.) (Dec. 20, 1983.)

July 18–20 Seismic Deconvolution Workshop, Vail, Colo. Sponsor, SEG. (Sven Treitel, Amoco Production Co., Research Center, P.O. Box 591, Tulsa, OK 74102.) (Feb. 7, 1984.)

July 19–23 Symposium on Wave Breaking, Turbulent Mixing, and Radio Probing of the Ocean Surface, Sendai, Japan. (O. M. Phillips, Dept. of Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 21–28 Eighth World Conference on Earthquake Engineering, San Francisco, Calif. Sponsor, Earthquake Engineering Research Institute (EERI), ACU. (J. Penzien, Chair-8WCEE, EERI, 2620 Telegraph Ave., Berkeley, CA 94704.)

July 23–25 Summer Computer Simulation Conference, Boston, Mass. Sponsor, Society for Computer Simulation. (U. W. Wade, 1984 SCSC Program Chairman, Wade Engineering P.C., P.O. Box 8419, Huntington, NY 11743; tel.: 516-271-6073.)

July 25–26 11th International Symposium on Urban Hydrology, Hydraulics, and Sediment Control, Lexington, Ky. Sponsor, Univ. of Kentucky. (E. Haden, Coordinator, Office of Continuing Education/Engineering, 223 Transportation Research Bldg., Univ. of Kentucky, Lexington, KY 40506-0046; tel.: 606-257-3972.) (Nov. 15, 1983.)

July 24–28 Water Rights Specialty Conference, Flagstaff, Ariz. Sponsors, Ground Water Committee and Surface Water Committee of the ASCE Irrigation and Drainage Division. (Kenneth C. Renard, Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719; tel.: 602-629-6381.)

July 26–27 A Joint Workshop of the Committee on Climatic Changes and the Ocean and the Joint Scientific Committee for World Climate Research Panel, Sendai, Japan. (O. M. Phillips, Dept. Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 30–August 2 Seminar on Water Management Practice, Zaria, Nigeria. Sponsors, International Association for Hydraulic Research and UNESCO. (Gunnar Lindh, Dept. of Water Resources Engineering, Lund Institute of Technology, Fack 725, S-220 07 Lund, Sweden.) (Dec. 8, 1983.)

July 30–August 3 Borogeophysics Assembly, Louvain-la-Neuve, Belgium. Sponsor, European Geophysical Society. (C. M. Brown, Dept. of Physics, Univ. College of Wales, Aberystwyth, Wales, UK.) (Dec. 20, 1983.)

July 31–Aug. 2 Fourth International Symposium on Stochastic Hydraulics, Univ. of Illinois, Urbana-Champaign. Sponsors, IAHR and ACU. (Ben C. Yen, Wilson H. Tang, or Glenn E. Stout, Univ. of Illinois, 208 N. Romine St., Urbana, IL 61801; tel.: 217-333-0687 or 333-0536.) (Nov. 8, 1983.)

July 31–August 5 Workshop on Fission Track Dating, Troy, N. Y. Sponsors, General Electric R&D Lab., SUNY at Albany, and Rensselaer Polytechnic Institute. (Donald S. Miller, Dept. of Geology, Rensselaer Polytechnic Institute, Troy, NY 12181.)

Aug. 4–14 27th International Geological Congress, Moscow, USSR. Sponsors, USSR National Committee for Geology, IUGS. (Organizing Committee of the 27th IGC, Institute of the Lithosphere, 22, Staromonetny, Moscow, 109180, USSR.)

Aug. 6–9 Chapman Conference on the Magnetospheric Polar Cap, Fairbanks, Alaska. (Polar Cap Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.) (Jan. 24, 1984.)

Aug. 12–16 20th Annual AWRA Conference and Symposium, Washington, D. C. (Arlene Dietz, U.S. Army Corps of Engineers, Institute for Water Resources, Casey Bldg., Fort Belvoir, VA 22060; tel.: 703-355-2508.) (Aug. 16, 1983.)

Aug. 13–17 12th International Laser Radar Conference, Aix-en-Provence, France. Sponsors, IAMAP and AMS. (G. Megie or J. P. Granier, Service d'Aéronomie du CNRS, 12th International Laser Radar Conference, BP 3, 91370 Verrières le Buisson, France.) (Nov. 8, 1983.)

Aug. 14–17 Specialty Conference on Water for Resource Development, Coeur d'Alene, Idaho. Sponsor, Hydraulics Division of ASCE. (Harry Tirrel, American Society of Civil Engineers, 345 E. 47th St., New York, NY 10017-2398; tel.: 212-705-7494.)

Aug. 21–29 International Radiation Symposium '84 (IRS), Perugia, Italy. Sponsor, IAMAP Radiation Commission. (Giorgio Fiocco, Chairman IRS '84, Dipartimento di Fisica, Città Universitaria, 00185 Rome, Italy; telex: INFNRO 613255.)

Aug. 26–29 Field Conference on Open-System Behavior in Magnetic Evolution: Petrological, Oceanographical, Geochemical and Geophysical Constraints, Taos, N. Mex. Sponsor, Institute for the Study of Earth and Man. (Mike Dungan, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275; tel.: 214-692-2750.) (Jan. 17, 1984.)

Aug. 26–29 Geothermal Resources Council 1984 Annual Meeting, Reno, Nev. (Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617; tel.: 916-758-2360.) (Feb. 7, 1984.)

Aug. 26–31 Seventh Australian Geological Convention, Sydney, Australia. Sponsor, Geological Society of Australia. (Secretary 7 AGC, P.O. Box 589, North Ryde, NSW, Australia 2113.) (Nov. 29, 1983.)

Aug. 27–31 Seventh IAHR Symposium on Ice, Hamburg, Germany. (J. Schwarz, Ice Engineering Div., Hamburgische Schiffbau-Versuchsanstalt GmbH., P.O. Box 600 929, 2000 Hamburg, FRG.) (Nov. 22, 1983.)

Aug. 27–Sept. 6 General Assembly of URSI, Florence, Italy. (Vito Cappellini, IROE, Via Panciatichi 64, 50127 Firenze, Italy.) (Dec. 27, 1983.)

Sept. 3–7 Quadrennial Ozone Symposium, Halkidiki, Greece. Sponsors, IAMAP International Ozone Commission (IOC), Commission of the European Communities, the Academy of Athens, and WMO. (Christos S. Zerefos, Chairman, Local Organizing Committee, Physics Dept., Campus Box 149, Univ. of Thessaloniki, Thessaloniki, Greece. Send copy of information request to C. D. Walshaw, Secretary, IOC, Clarendon Laboratory, Oxford Univ., Parks Rd., Oxford, OX1 3PU, UK.)

Sept. 10–12 Oceans 84 Conference and Exhibition, Washington, D. C. Sponsors, Marine Technology Society, AGU, and Institute of Electrical and Electronics Engineers/Oceanic Engineering Society. (Oceans 84 Technical Program Committee, 1730 M St. N.W., Suite 412, Washington, DC 20036.) (Nov. 29, 1983.)

Sept. 10–14 International Symposium on Hydromechanical Balances of Fresh Water Systems, Stockholm/Uppsala, Sweden. Sponsors, Swedish Natural Science Research Council, UNESCO, and IAHS. (M. Falkenmark, Exec. Sec. NFRS, Comm. for Hydrology, Box 6711, S-11385 Stockholm, Sweden.)

Sept. 12–14 Seminar on Degradation, Retention, and Dispersion of Pollutants in Groundwater, Copenhagen, Denmark. Sponsor, International Association on Water Pollution Research and Control. (Erik Arvin, Dept. of Environmental Engineering, Building 115C, Technical Univ. of Denmark, DK-2800 Lyngby, Denmark.) (Dec. 13, 1983.)

Sept. 20–21 International Symposium on Environmental Pollution, Site To Be Announced. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

Sept. 24–25 Seminar: Enhanced Biological Removal of Phosphorus From Wastewater, Paris, France. Sponsor, International Association on Water Pollution Research and Control. (Michel Florentz, Phosphorus Seminar, Anjou-Recherche, 52, Rue d'Anjou, 75384 Paris Cedex 08, France; Tel.: 266–91–50; telex: Gyneaux 280 332 F.) (Sept. 6, 1983.)

Sept. 24–26 International Water Well Exposition, Las Vegas, Nev. Sponsor, National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Sept. 26–28 Seventh National Groundwater Quality Symposium, Las Vegas, Nev. Sponsor, National Water Well Association. (NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Oct. 1–5 International Symposium on Recent Investigations in the Zone of Aeration, Munich, FRG. Sponsor, Technical Univ. of Munich. (P. Udluft, RIZA Symposium, Institut für Wasserchemie der TU München, Marchioninistr. 17, D-8000 Munich 70, FRG.) (Dec. 20, 1983.)

Oct. 3–5 Symposium on Meteorology and Oceanography of Northern High Latitudes, Anchorage, Alaska. Sponsors, American Meteorological Society and AAAS. (Stuart Bigler, National Weather Service, 701 C St., P.O. Box 23, Anchorage, AK 99513.) (March 6, 1984.)

Oct. 8–11 World Conference on Remote Sensing, Bayreuth, FRG. Sponsors, Univ. of Bayreuth, Texas Christian Univ. Center for Remote Sensing and Energy Research, and International Society of Toxicological and Environmental Chemists. (Lea W. Newland, Director, Environment Sciences Program, Texas Christian Univ., Fort Worth, TX 76129; tel.: 817-921-7271.) (Feb. 7, 1984.)

Oct. 10–12 Seismological Society of America Eastern Section 56th Annual Meeting, St. Louis, Mo. (Robert B. Herrmann, Dept. of Earth and Atmospheric Sciences, St. Louis Univ., P.O. Box 8099, St. Louis, MO 63156; tel.: 314-658-3120.)

Oct. 10–15 New Mexico Geological Society 35th Annual Field Conference, Taos, N. Mex. (R. Riecker, General Chairman, Los Alamos National Laboratory, Mail Stop D440, Earth and Space Sciences Div., Los Alamos, NM 87545.) (Nov. 1, 1983.)

Oct. 16–19 International Symposium on Lake and Watershed Management: Local Involvement, McAfee, N.J. Sponsor, North American Lake Management Society. (Harry Gibbons, Jr., Dept. of Civil and Environmental Engineering, Washington State Univ., Sloan Hall 141, Pullman, WA 99164–2912.) (March 6, 1984.)

Oct. 17–19 AIPG Annual Meeting, Orlando, Fla. (Bobby J. Timmons, General Chairman, Timmons Associates, P.O. Box 50608, Jacksonville, FL 32250; tel.: 904-246-4553.)

Oct. 31–Nov. 7 Regional Assembly of IASPEI, Hyderabad, India. (Mohan L. Gupta, Organizing Committee, IASPEI Regional Assembly, National Geophysical Research Institute, Hyderabad-500 007, India; telex: 155–478 NGRI IN; cable: Geophysics.) (Aug. 25, 1983.)

Nov. Mexican Geophysical Union Annual Meeting, La Paz, Baja California Sur, Mexico. (Union Geofísica Mexicana, A.C., Comité Organizador Reunion 1984, Apartado Postal 1805, Ensenada 22800. B.C.N. Mexico.)

Nov. 5–8 GSA Annual Meeting, Reno, Nev. (Jean Latulippe, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Nov. 12–17 Water for South Africa, Johannesburg, South Africa. Sponsors, National Water Well Association and the Borehole Water Association of Southern Africa. (David M. Nielsen, Conference Coordinator, NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.) (Dec. 13, 1983.)

Dec. 3–7 AGU Fall Meeting, San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 16–21 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii. Sponsors, ACS, Chemical Institute of Canada, and Chemical Society of Japan. (PAC CHEM '84, Meetings and Divisional Activities Dept., ACS, 1155 16th St., N.W., Washington, DC 20036; tel.: 202-872-4396; PAC CHEM '84, Chemical Institute of Canada, 151 Slater St., Suite 906, Ottawa, Ontario K1P 5H3, Canada; tel.: 613-233-5623; PAC CHEM '84, Chemical Society of Japan, 1–5, Kanda-Surugadai, Chiyoda-ku, Tokyo 101, Japan; tel.: 03-292-6161.) (Sept. 13, 1983.)

Dec. 28–31 Fourth International Conference on Applied Numerical Modeling, Tainan, Taiwan. (S. Y. Wang, School of Engineering, Univ. of Mississippi, University, MS 38677; tel.: 601-232-7219.)

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Jan. 7–12 17th International Congress on Hydrogeology of Rocks of Low Permeability, Tucson, Ariz. Sponsors, International Association of Hydrogeologists, AGU. (E. S. Simpson, Dept. of Hydrology and Water Resources, College of Engineering, Univ. of Arizona, Tucson, AZ 85721.)

March 10–15 American Society of Photogrammetry and American Congress on Surveying and Mapping National Meeting, Washington, D.C. (Willard A. Kimrey, 1115 Jensen Pl., Fairfax, VA 22032; tel.: 703-425-8790.)

April 1–4 European Union of Geosciences Biennial Meeting, Strasbourg, France. (Organizing Committee, Dept. of Earth Sciences, Univ. of Cambridge, Downing St., Cambridge CB2 3EQ, UK.)

April 9–11 Fifth Annual Front Range Branch Hydrology Days, Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State Univ., Fort Collins, CO 80523; tel.: 303-491-5118 or 8519.)

May 27–31 AGU Spring Meeting, Baltimore, Md. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Summer Colloquium on Comparative Study of Magnetospheric Systems, France. (Dominique Le Quéau and Bent Mosdlles-Pedersen, DASOP, Observatoire de Meudon, F 92195, Meudon Principal Cedex, France. Telex: 200 590 CNEL 985.) (Aug. 9, 1983.)

June 9–15 IWRA Fifth World Congress, Brussels, Belgium. (Fifth World Congress On Water Resources, Brussels International Conference Centre, Parc des Expositions, Centenairestellingspark, B-1020 Brussels, Belgium; tel.: 32-2-478-48-60; telex: 23-643.) (Aug. 30, 1983.)

June 26–28 U.S. Symposium on Rock Mechanics, Rapid City, S. Dak. Sponsor, South Dakota School of Mines and Technology. (Eileen Ashworth, Chairman, 26th U.S. Symposium on Rock Mechanics, Dept. of Mining Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701-3995; tel.: 605-394-2344.)

Aug. 5–16 IAMAP/IAPSO Joint Assembly, Honolulu, Hawaii. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Aug. 5–17 Symposium on Magnetic Anomalies over the Margins of Continents and Plates, Prague, Czechoslovakia. Sponsor, International Association of Geomagnetism and Aeronomy. (William J. Hinze, Dept. of Geosciences, Purdue Univ., West Lafayette, IN 47907; tel.: 317-494-5982.) (Feb. 7, 1984.)

Aug. 19–23 Sixth Gondwana Symposium, Columbus, Ohio. Sponsor, GSA. (D. Elliot, Ohio State Univ., Institute of Polar Studies, 103 Mendenhall, 125 South Oval Mall, Columbus, OH 43210.)

Aug. 19–30 23rd General Assembly of IASPEI, Tokyo, Japan. (Ryosuke Sato, Secretary-General of the 23rd General Assembly of IASPEI, c/o Inter Group Corp., Akasaka Yamakatsu Bldg., 8-5-32, Akasaka, Minato-ku, Tokyo 107, Japan; tel.: Tokyo (03) 479-5131.)

Sept. 16–21 Symposium on Potassic Volcanism and Etna Volcano, Catania, Italy. Sponsor, IAVCEI. (G. Frazzetta and G. Lanzafame, Istituto Internazionale di Vulcanologia, V.le R. Margherita, 6, Catania, Italy.) (Dec. 27, 1983.)

Sept. 17–21 AIPG Annual Meeting, St. Paul, Minn. (Robert E. Prendergast, General Chairman, Geotechnical Engineering Corp., 1925 Oakcrest Ave., Roseville, MN 55113; tel.: 612-636-7744.)

Oct. 14–17 GSA Annual Meeting, Boston, Mass. (Jean Latulippe, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Dec. 9–13 AGU Fall Meeting, San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

AAAS American Association for the Advancement of Science
AAPG American Association of Petroleum Geologists
ACS American Chemical Society
AIPG American Institute of Professional Geologists
AMS American Meteorological Society
ASCE American Society of Civil Engineers
AWRA American Water Resources Association
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHR International Association for Hydraulic Research
IAHS International Association of Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association for the Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
ICSU International Council of Scientific Unions
IUGG International Union of Geodesy and Geophysics
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science
WMO World Meteorological Organization

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6740 Earthquake Prediction
A SEISMOTECTONIC ANALYSIS OF THE ANZA SEISMIC GAP, SAN JACINTO FAULT ZONE, SOUTHERN CALIFORNIA
C. O. Sanders (Seismological Laboratory, California Institute of Technology, Pasadena, California, 91125), H. Kanamori.

Small earthquake epicenters near the Anza seismic gap define a 20 km quiescent segment of fault bounded to the northwest and southeast by areas of relatively high seismicity. Recent moderate earthquakes on and near the San Jacinto fault in the gap and their relatively depressed aftershock activity indicate that the fault is seismogenic and highly stressed but locked by some mechanism. The locked nature of the fault may be due to relatively high compressive stress normal to the fault resulting from the convergent geometries of the local, active, discontinuous faults and the oblique orientation of the regional maximum compressive stress. Strain is not being relieved by aseismic fault creep. A swarm of small earthquakes in the central block 13 km southwest of the Anza gap beneath the Cahuilla Valley recently released stress in an area which was previously highly active before the 1918 (M 6.8) and 1937 (M_L 6.0) earthquakes. The occurrence of these periods of increased seismicity near Cahuilla in the years immediately before the nearby (closer than 35 km) large earthquakes and the swarm suggest that the ground beneath Cahuilla may be acting as a stress-meter signaling the presence of high stresses before large local earthquakes. The length of the quiescent fault segment suggests potential for about an M 6.5 earthquake if the entire segment ruptures at once.
J. Geophys. Res., B, Paper 4B0173

6750 Seismology (Seismic Sources)
PATTERNS OF EARTHQUAKES AND THE EFFECT OF SOLID EARTH AND OCEAN LOAD TIDES AT MOUNT ST. HELENS PRIOR TO THE MAY 18, 1980 ERUPTION
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Seismographs near Mount St. Helens Volcano recorded an earthquake swarm lasting nearly 2 months prior to the catastrophic May 18, 1980, eruption. The earthquakes are divided into four classes based on station CRW (Δ = 110 km) seismograms characteristics: 1) events with BV/P amplitude ratio > 3 and dominant frequency > 3 Hz; 2) events with BV/P ratio between 1 and 3 and dominant frequency > 2 Hz; 3) events similar to (2) but with a strong (probably surface wave) phase just after the S-phase; and 4) events with frequencies between 1-2 Hz lacking a clear S-phase. The seismicity pattern for each of the four classes is unique, and we assume each group of events with similar waveforms represents a common physical process, depth, source area, or

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